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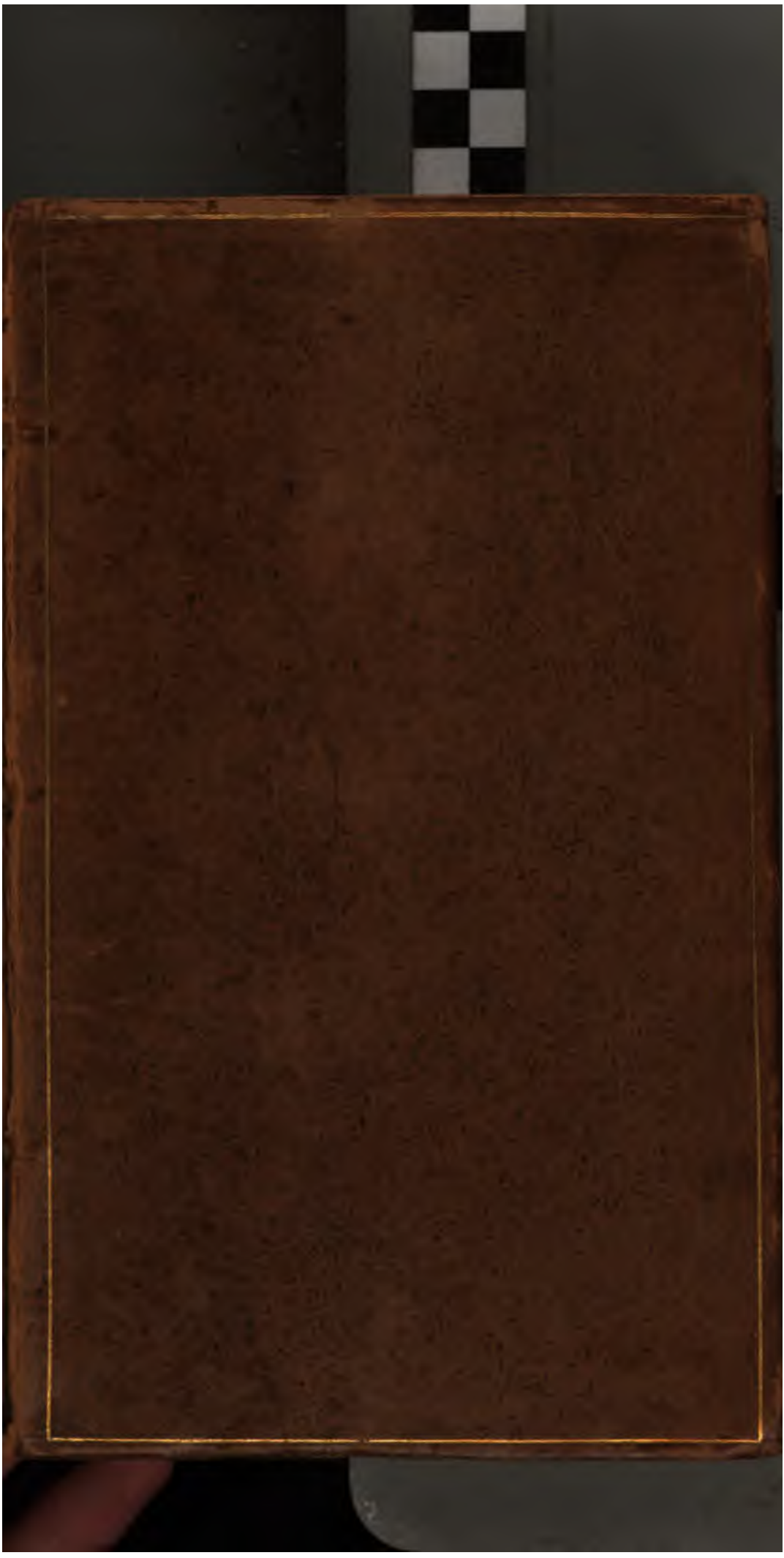

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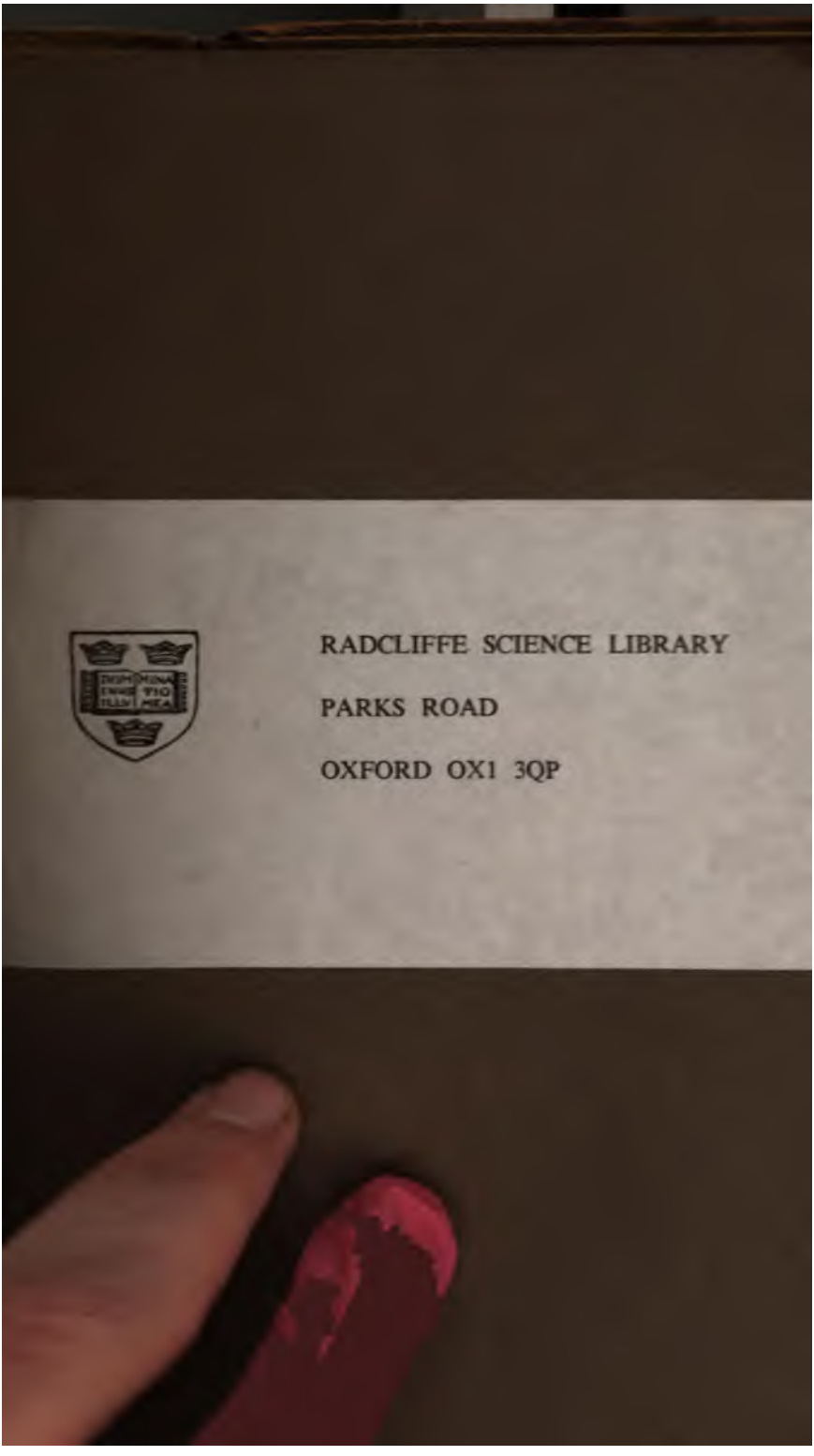

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THE

NATURAL HISTORY

OF THE

MINERAL KINGDOM,

RELATIVE TO

THE STRATA OF COAL, MINERAL VEINS, AND THE PREVAILING STRATA OF THE GLOBE.

IN TWO VOLUMES.

BY JOHN WILLIAMS, F.S.S.A.

MINERAL SURVEYOR.

THE SECOND EDITION.

WITH AN APPENDIX, CONTAINING A MORE EXTENDED VIEW OF MINERALOGY AND GEOLOGY.

ILLUSTRATED WITH ENGRAVINGS.

BY JAMES MILLAR,

M.D. F.S.A.S.

And Lecturer on Natural History and Chemistry, Edinburgh.

VOL. I.

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1810.

PREFACE,

WITH A SHORT NOTICE OF THE

LIFE OF THE AUTHOR.

It is now above twenty years since the first edition of this Work appeared. It was then received, and still continues to be regarded, as the most valuable practical treatise on the Natural History of Coal which has yet been offered to the public.

In bringing forward the present Edition, I have endeavoured to improve the Author's language, which, although always perspicuous, and frequently vigorous, is often remarkable for its diffuseness and tautology. But the task of curtailing it of those redundancies and repetitions, which seemed unnecessary in the way of useful illustration, has been executed with a sparing hand; so that to some readers it may appear that the style of the Work still retains a good deal of the less agreeable features of its original character. The subdivision of the Work into Chapters, and the exclusion of several long discussions on subjects unconnected with geological investigations, are

the only other alterations which I have presumed to make.

It was at first intended to add explanatory notes to the original text of the Author, referring, for fuller illustration of any point that seemed to require it, to an Appendix proposed to be given to each of the parts into which the Work is divided; and, accordingly, this plan was so far pursued, even after the printing commenced, as will appear by the references at pages 31 and 46 of Vol. I. which must now be expunged. It has, I believe, rarely happened that notes and illustrations, whether connected with an original Work by the Author himself, or by an Editor, are so skilfully arranged, as to be entirely free from embarrassment to the reader. Aware of this inconvenience, which in the present case was likely to swell out to a considerable magnitude, I was induced to change the plan first thought of, for that which has been adopted; the advantages of which are, that the original Work and the Appendix, which are mutually illustrative of the same subjects, are in a great measure independent, so that each may be perused separately as a whole.

The Appendix, which occupies the greater part of the second Volume, contains a rapid sketch of the proper objects of mineralogy, as well as a comprehensive system of geology; and whatever be the merits or defects in the execution of this part of the Work, I may assert with some confidence,

that it includes a more copious detail of geological facts than any other work in the English language.

The publishers of the present edition of this Work having expressed a wish that a short biographical notice of the Author should be prefixed to it, I made various applications to those quarters which seemed to be the most probable sources of information; but all that I have been able to collect may be compressed in a very few words.

Mr WILLIAMS was a native of Wales, and was originally bred a miner. He was some time a soldier in the Dutch service; after which he was engaged at Leadhills to superintend the process of extracting silver from lead. It does not appear that he was long in that situation; for, soon after he came to Scotland, he was employed by some proprietors in the vicinity of Edinburgh to search for lead ore. He then became tacksman of the coal of Carlops on the estate of Newhall, which he has described as the extreme boundary of the coal-field of Midlothian. Unsuccessful in this undertaking, it was probably soon relinquished for an engagement with the Earl of Moray, to search for coal on his estate of Dunrobin, in the north of Scotland. In these trials, it is scarcely necessary to add he was disappointed.

Mr WILLIAMS lived for some years at Gilmerton, near Edinburgh, as manager of the coalworks at that place. Here he put together and prepared

for the Press the materials for his Mineral Kingdom, for which he had enjoyed the most favourable opportunities of collecting information, in the various pursuits which occupied his attention through life. While he resided at Gilmerton, he was frequently called out as a coal viewer, or mineral surveyor. He afterwards went to Italy, to search for coal and copper mines; but by whom that speculation was proposed, I have not been able to learn. He died soon after his arrival in that country.

The only traits of the Author's character which I can venture to delineate, must be derived from this Work, in which he discovers himself to have been a man of acute observation and nice discernment, of great activity, and ardour of mind; and, what is not unusual in such characters, the warmth of his enthusiasm, on the peculiar subjects of his contemplation, seems at times to have led him too far into visionary speculations.

JAMES MILLAR.

Brown's Square, Edinburgh,
20th April, 1810.

CONTENTS

OF

VOLUME FIRST.

PART I.

Page.

OF THE NATURAL HISTORY OF THE STRATA OF COAL, AND OF THE CONCOMITANT STRATA 1

CHAP. I. Of the regular arrangement of the strata of coal - - - ib.

II. Of the derangement of the strata of coal 9

III. Examples of sections of the strata of coal in different places - - 38

IV. Of the different kinds of sections of the strata, of stratification, and of the thickness of a seam of coal at different depths 51

V. Of the strata in contact with the strata of coal - - - - - 65

VI. Of the different declivities of the strata of coal - - - 84

VII. Relative declivity of the strata of coal to the inclination of the surface - 95

VIII. Of the edge coal seams of Midlothian, and of the flat broad seams to the southward - - - - 105

IX. Of the extent of coal fields and coal countries - - - 109

Page.

CHAP. X. Of the indications of coal, and methods of searching for - - 133
XI. Of the formation and origin of coal 159
XII. Of the different kinds of coal - 175
XIII. Of the limited quantity of coal in Britain 184
XIV. Of the coal of Cape Breton and Newfoundland - - - 200

PART II.

OF THE NATURAL HISTORY OF MINERAL VEINS, AND OTHER REPOSITORIES OF THE USEFUL METALS 221

CHAP. I. Of rake veins - - 222
II. Of the mineral substances with which veins are filled - - - 235
III. Of irregular rake veins - 254
IV. Of partial veins - - 269
V. Of pipe veins, flat and accumulated veins 278
VI. Of the accidents to which mineral veins are subject - - 292
VII. Of other repositories of metallic ores 300
VIII. Of the symptoms of mineral veins - 318
IX. Of the different species of lead and copper ores - - - 347
X. Of copper mines in Scotland - 363
XI. Of the ores and mines of iron - 373

PART III.

OF THE NATURAL HISTORY OF THE PREVAILING STRATA, AND OF THE PRINCIPAL PHENOMENA UPON THE SURFACE OF OUR GLOBE - 387

CHAP. I. Of the prevailing rocks of Britain, and of the degrees of their stratification 390
II. Of the stratification of the globe, of the continuity of the regular strata, and

Page.
of the interruptions to which they are subject - - - 425
CHAP. III. System of Buffon examined, and compared with the real structure of the surface of the globe - 449
IV. Of the natural history of mountains, of their structure, and external phenomena - - - 468
V. Of the component parts of rocks 495
VI. Of the proofs of the universal deluge, derived from the strata of coal, and the general appearance of the surface of the globe - - 508

THE

MINERAL KINGDOM.

PART I.

THE NATURAL HISTORY OF THE STRATA OF COAL, AND OF THE CONCOMITANT STRATA.

CHAP. I.

OF THE REGULAR ARRANGEMENT OF THE STRATA OF COAL.

A SEAM or bed of coal is a real stratum, which is found to be fully as regular as any of those other concomitant strata found in the coal field, lying above and below the coal, or indeed of any other of the various strata which compose the superficies of our globe.

There is in many coal countries, and in many coal fields, a considerable number of strata or beds of coal, of various qualities and thickness, placed *stratum super stratum*, with a great variety of other strata interposed between them; and sometimes

different strata or seams of coal are so near to one another, that two, three, or more of them are cut through and worked in one pit. Every stratum of coal has some degree of declivity or slope, and a longitudinal bearing, and it stretches as far every way as the other strata which accompany it; and therefore it must be concluded, that coal is not an adventitious recent production, but that every stratum of it bears its proportion in composing the superficies of the globe, and that the strata of coal are coeval with the other strata which accompany them.

As there is nothing so effectual as local examples to enable us to form proper ideas in inquiries of this nature, let us go to the rocky shores of the ocean, or to some river which has cut deep into the rock, and choose out a fair and lofty section of the strata; but care should be taken to choose a proper section: Now a section that is cut in a line parallel to the bearing of the strata, is not a proper one; nor should the strata be too thick, as very thick strata of stone are apt to be broken transversely from the beds of the strata, and it is not easy to distinguish the real beds or stratification of the rock from the transverse cutters. I have frequently seen very thick beds of stone broken transversely into such equal and parallel divisions, that it required a good deal of attention to distinguish the real beds of the strata from these transverse cutters.

The best section for assisting our ideas to form proper notions of the disposition of the strata, is one cut in a line nearly parallel to the declivity of the strata, that is, in a line nearly from dip to rise, and where the strata are mostly thin, or of middling thickness, and the divisions of the several beds perfectly distinct. In such a section the several strata of various thickness and qualities are seen lying one above another, in as regular order as the leaves of a book.

If the strata decline a little with an easy slope, the section is the better adapted for this examination, as in that case the one edge of each stratum will dip down gradually out of our sight, and the other edge will be seen to rise up quite to the grass roots; and this order, in the disposition of the strata, is the most convenient imaginable for society, as it favours the discovery and working of coals, quarries, &c.

We find, that strata of coal do not always continue so good and regular near the surface of the ground as some others of a harder texture. Limestone, whinstone, basaltes, and many other hard rocks, continue firm and good quite up to the superficies of the strata; whereas, on the contrary, many of the softer and weaker strata crumble, or dissolve, near the surface, so that they are decomposed, and fall into sandy particles, which are mixed with the soil, or carried down the stream.

Immediately below the surface, many coals are

not more goodly to look to than a heap of soot; and in such situations many beds of fine freestone are entirely decomposed, and exhibit nothing but a layer of sand: Nevertheless, further down, under proper cover, the seams of coal, and other soft strata which accompany them, acquire strength and consistence, and preserve their thickness and their relative situation as regularly as other harder strata.

In a fair and regular section of the strata, we perceive that they preserve the same distance from one another above as they do below. Let us fix, for example, upon any two distinct layers, or strata, at several yards distance from one another, and stretch a horizontal line below, from the base of the one to the base of the other; we will suppose that the line measures a hundred feet. Now, if the same length of line is stretched horizontally up at the surface, we will find that it spans them above as well as below, and that they are nearly the same distance from one another. The upper edge of every individual stratum in the section is called by Scotch colliers the *crop* of it; and if it appears to the day, it is called the *outburst* of the stratum. In England, they say it *bassets out*. Now, as the distance betwixt the two different strata is a hundred feet at the surface, and the same below, it will be found, that the strata of this section keep the same line of bearing, and the same declivity or slope, for half a mile, or any given distance;

and in that case the two layers or strata fixed on will continue at the same distance from one another all the way, so long and so far upon the line of bearing, as the strata preserve the same degree of declivity. If they turn flatter, or nearer to the horizontal position, then the crops of them will be found at a greater distance; but if they are elevated to a greater degree of slope, or nearer the vertical position, in that case they will be found nearer to one another, in proportion to the greater or lesser degree of slope.

From this observation, it appears that the same classes or ranges of strata always run parallel to one another. What I mean by a range or class of strata, is any number of strata that lie contiguous to, and accompany one another, and that are disposed one above another in the same place; as, for instance, the number of seams of coal and the other strata which accompany them in the same coal field. These are all disposed one above another in regular order, as I have shown in the section under review, and they all run parallel to one another to any distance; for if one of them suffer any interruption, disturbance, or change, they generally all suffer the same; and when they have got over such trouble or interruption, they all floor regularly again, so that the parallelism of the same range of strata is always preserved.

Every stratum in a whole range, or class, or coal field, is spread out to a vast extent in an in-

clining plane, we may suppose, of a mile, or of several miles square, like an inclining field, or face of a country. A dead level line, drawn through this inclining plane, is called the *bearing* of the strata; and another line, drawn right across the dead level or bearing, is called the *declivity* of the strata, or the *dip* and *rise* of the strata. We generally can see but a very little way from the rise to the dip, or along the line of declivity of the strata, because the strata soon dip down out of our sight, and generally a great number of other strata come on above them; but, on the contrary, we can sometimes trace the same individual stratum, or number of strata, along the surface, or dead level line, for several miles; and therefore we may properly call this the *longitudinal line of bearing*.

It very frequently happens that the strata stretch or spread as far upon the latitudinal line of declivity as they do upon the longitudinal line of bearing; but then we cannot see them so far. We often see the superficies of the strata in different places upon the line of bearing bursting out, and appearing to the day, in rivers, rivulets, rocks, scars, &c.; and we frequently work quarries, and especially coals, to a considerable length upon the stretch of this line; whereas the strata upon the stretch of the line of declivity are soon concealed out of our sight. From these observations, it appears that every individual stratum in the whole section keeps its station where you see it placed,

and that it spreads as wide, and stretches as far, as any of those which are placed above and below it, which perhaps may be for several miles every way. Now, a seam of coal being a regular stratum, it must follow of consequence, that when the crop or outburst of a seam is once discovered, it will spread as wide every way as any of the other strata which are found to accompany it.

The stratum which is placed immediately above the seam of coal is properly called the *roof* of the coal, and the stratum which is placed immediately below a seam of coal is properly called the *pavement* of the coal. Now, these three, that is, the stratum of coal, and its roof and pavement, with the other concomitant strata lying above and below them, always preserve their stations and parallelism; that is, they are all stretched out and spread one above another upon the same inclining plane, and they have the same line of bearing and the same line of declivity.

When a young naturalist has viewed a few regular sections of the strata, and has considered a little the stretch or spreading out of the regular strata, as described above; when he afterwards descends into a coalwork, and is shown the sections of the seams of coal, and other strata cut through in sinking the pit; when he examines the seam of coal which they are then working, and finds it preserve an equal thickness between roof and pavement, perhaps for several hundred

yards from the pit bottom; when he has seen the whole coal wall, that is the unwrought coal, and all the boards or rooms in which the colliers are working, with a prodigious number of coal pillars left for supporting the roof, and finds the coal every where of nearly the same thickness, and preserving nearly the same declivity or slope—the first thing that strikes his imagination, next to the novelty of the whole scene, is the extreme regularity of the stratum of coal so deep down, and to such an extent below ground; and he will perhaps imagine it a very easy matter to pursue and work out a seam of coal to any extent, even through the whole length of the island: but experience does not find it so easy a task as a sanguine theorist may be apt at first to imagine.—Experience meets with numberless rubs and interruptions in working coal; many of which occasion great trouble and expence, and some of them prove the loss of the coal altogether, either by its being cut off, or rendered unfit for working with profit.

An accurate knowledge of the strata in a coal field is indispensably necessary; and this knowledge is to be obtained by entering the pits, mines, and levels sunk and driven in the coal field. In these the different strata of stone, and of the other coal metals, thick and thin, hard and soft, will be distinctly seen. An accurate coal-master will make himself well acquainted with the quality, colour,

and thickness of each of these, and how far each of them is above or below such and such a seam of coal. He will carefully consider the order of the different strata, as they lie *stratum super stratum* with respect to one another; by which means, when he sees any one of them, he knows what others are to be found next to it, both above and below.

CHAP. II.

OF THE DERANGEMENT OF THE STRATA OF COAL.

THE accurate knowledge of the distribution of the coal, and other strata, will often be of singular use: As for instance, when the coal is thrown either up or down by one of those slips which I am by and bye to describe. In that case the coal appears to be lost. What method then is to be adopted in order to recover it? That cannot properly be resolved upon, until it is known first how far it is thrown out of its regular course, up or down. The readiest way to be master of this interesting point, is to pierce the stone, or rather strata, which faces the workmen, where the coal is cut off and lost; and if the miner knows it with certainty, he is encouraged, as in that case he

knows pretty nearly how far the coal is thrown off its ordinary level, either up or down; and he can then judge which is the most proper method to recover it with least expence of time and money.

The coal is sometimes thrown a great way out of its former course by great dykes and slips, which frequently make it necessary to search for it upon the other side of such *troubles*; and many accidents happen which make it sometimes necessary to shift the former station altogether, and to sink new pits, &c.; in which cases, an acquaintance with the history of the strata which accompany the coal becomes absolutely necessary, and the want of it makes many to grope in the dark, and often to commit blunders at a great deal of unnecessary expence and loss of time.

Some of the strata which lie near the coal are frequently seen cropping out in rivulets, and other places where the superficies of the strata appear, and an expert coal-master knows what use to make of such discoveries. He will be very careful to investigate all he sees from time to time, until the place, and disposition, and other phenomena of all the strata in the coal field are become familiar to him.

I shall now give a history and description of such breaks and interruptions of the regularity of the strata as are commonly met with in working coals.

The slips, dykes, gashes, and other accidents

which are met with in working coals, are all of them in general, and not improperly, called *troubles* by Scotch colliers.

I. The *slip*, properly so called by the English colliers, but improperly called a *dyke* by most of the Scotch colliers, is the most frequent accident or interruption which we meet with in working coals. In a slip, the strata are all cut or broken asunder, frequently in a straight line, though sometimes in a curved line; and those upon the one side of the breach or section are slipt down a considerable number of feet, perhaps many fathoms, below the edges of the same strata upon the other side of it. In some coal fields, the metals or strata are thrown up by one slip as much as they are thrown down by another; and in other fields, all the slips which we meet in working away the coal towards one point of the compass are up slips, which in course would be all down if you were working towards the opposite point.

There is no coal-work of any considerable extent without slips. In pointing out a slip to a young student in this branch of natural history, it will be proper for his conductor to show him the coal wall in perfection, as near the slip as he can, where he will find the coal nearly of the same thickness as in other parts of the work; and by shifting the candle slowly forward along the coal

wall a few yards, he will see the slip. If it be a down slip, he will see the coal beginning to be cut off first above near the roof, and so downwards, by degrees, to the pavement, not always in a perpendicular, but generally in a sloping line, though some slips stand much nearer the perpendicular than others. When, in a down slip, the coal is cut off in this manner, you will meet with stone or other metals * instead of it, first near the roof; and the stone continues to meet the workmen in the face, or in the place where the coal should be with a slope downwards, until at last, down at the pavement, the whole stratum of coal is cut off, and no more of it remains in sight. To a person of no experience in these matters, the coal in this instance appears to be cut off altogether, nor would he know what was to be done in order to find it again; but an experienced coal-master has pretty good rules by which he can recover it. As the coal in this down slip began first to be cut off at the roof, and so gradually downwards, until it was entirely cut off at the pavement, your conductor, with the point of a pick, can open up a little of the vise or fissure in the pavement; and in that fissure you will perceive

* When I use the word *metals*, in treating of coal, I mean such strata of different colours and qualities as are commonly found accompanying seams of coal.—AUTHOR.

some vestigia of the coal remaining. Sometimes an inch or two, or more, of the coal is seen going down into the fissure; but frequently nothing is found in the section or fissure but a blackish soft sticking of clay, perhaps not above half an inch thick. I have seen the joint so very close, that there was hardly room to thrust the blade of a knife betwixt the two hard sides of the fissure; nevertheless the section or fissure continued to be distinctly seen with two smooth sides. It will then be proper to show our young learner where the slip has been pierced by a mine; and when he has gone through the mine to the other side, he will see, that from thence the same trouble becomes an up slip. Above, upon the other side, the coal began first to be cut off at the roof; but, on the contrary, it begins here to be first lost below at the pavement, and the stone comes in instead of it gradually upwards, until all the coal is entirely cut off at the roof. You will find the coal flooring as regularly down, upon the low side of the slip, as it was above on the other side of it before it was cut off; and if the mine has been made in the vise or fissure of the slip, you will see some dark vestige of the coal all the way through, from the place where the coal was cut off, upon the one side of the slip, until it floors regularly again, at full thickness, upon the other side of it; at least you will perceive a section or fissure cutting all the strata in a slanting direc-

ion from where the coal is lost above until it is found again below.

When we first meet with one of these troubles, we do not immediately know what to make of it, or how far it has thrown the coal up or down, unless we have pierced it before in some other part f the field, as they differ widely in magnitude, or in the number of feet, or of fathoms, they throw the coal off its ordinary floor or level; and they also differ widely in the confusion they make in the metals, and in the line of bearing; but they all agree in this one circumstance, that there is always a cut or fissure in the strata, though not always in a straight line; and that the section of the strata upon one side of the fissure is always thrown or sunk down below the section or edges of the same strata on the other side of the fissure.

Slips in the coal and coal metals are either parallel, direct, or oblique:

1*st*, By *párallel slips*, I mean such as cut the strata in a line parallel to the dead level line or bearing of the strata. The bearing in Great Britain, and other places in the same parallels of latitude, is nearly from north-east to south-west, excepting small spots or places where the strata have been partially warped or twisted out of the true line of direction by accidental causes, such as a different dip or declivity, which is occasioned by the waving and wheeling of the strata, &c. to be explained hereafter.

The effect of the parallel slip is this: When you are working a coal towards the dip, or pushing a mine towards the dip, in order to gain a greater breast of coal, you strike one of these slips, which meets you in the face as you push downwards, cuts off the coal, and throws it many feet or many fathoms up. Some of these slips throw the coal quite up to the surface, though you have sixty, eighty, or more fathoms of cover where it is cut off. The coal has generally the same, or nearly the same, declivity or dip upon both sides of one of these parallel slips, and likewise the same bearing; and therefore, when the coal is only thrown up a few feet, or a few fathoms, the interruption is easily overcome, by running a mine or level right across the strata, from the one side of the slip, until you cut the coal upon the other side of it. But when it happens to be a great slip, you have either a long mine to drive, in order to level the water upon the other side of the slip, and bring it to the adit or engine, or else you must remove the engine to a proper station, to gain as great a field of coal upon the other side of the slip as it is able to drain. It will be easily conceived, that in this instance, what is an up slip from one side, is a down slip from the other; that is, when you are working with your face to the dip, and meet an up slip, if you were working upon the other side of it, and working with your

face to the rise of the coal, it would be a down slip.

These parallel slips are frequently the occasion of our having such fine and regular sections of the strata as we often meet with upon the banks of rivers, cliffs of rocks, and the shores of the ocean. One of these slips, or perpendicular fissures, cutting the strata in a line, and that part of the range of stata which was without the fissure, or towards the crop of it, being undermined by water, or otherwise broken off, a regular section of the strata, from the top to the bottom of the rock, on the side which stood firm, is exhibited to view.

2*d*, The *oblique slips* are such as cut the strata in a diagonal direction across the slope. These slips differ but little from the former in description, only they throw the coal up or down in the same oblique direction, and they throw it to one side, out of the line of bearing, in proportion to the obliquity of the line of the fissure or slip to the line of bearing of the strata, and the number of feet or fathoms the coal is thrown up or down off its former level.

3*d*, The third species of slips, which I call *direct*, are such as cut the strata right across, nearly in a line from crop to dip. When you are carrying forward a breast of coal, which dips towards the north, and are working along the dead level line or bearing of the coal, with your face towards the west, and meet one of these direct or

rectangular slips, if it be a down-slip, the coal is thrown so far to the left hand out of the former line of bearing; but, on the contrary, if it be an up-slip, the coal is thrown to the right hand, in proportion to the number of fathoms it is thrown off its former level, and to the quick or slow rise and declivity of the strata. In this case, when it is a down-slip, a mine or level drift must be turned off to the left hand; but if an up-slip, it must be turned off to the right from the lowest or level room, and carried in the vise or fissure of the slip, in order to level the coal, and winn it properly upon the other side of the trouble. It may be proper to observe here, that you cannot depend with absolute certainty upon such mine or level for discovering the coal upon the other side of this trouble, until you first know that the slip is a single slip, for many large slips have several branches. In a single slip, which only throws the coal once up or down, you are sure to find the coal with a mine, as pointed out above, by keeping a good hold of the firm metals in the farther side of the mine, where the coal is to be found; that is, by cutting the edges of the solid strata in the farther side of the vise, or softness contained in the fissure of the slip. But if the slip consists of several branches, or, in other words, if there are two or three, or more slips near one another, which often happens before the coal is got clear of that trouble and floors again as before, it re-

quires farther attention. We sometimes meet with a range of troubles or slips, parallel to, and so near one another, that we must try to get beyond them all before the coal shall floor regularly. In that case, the mine or drift mentioned before is not sufficient. This mine is supposed to be driven in the vise of the slip, and the whole breadth or wideness of the mine is not above three feet; whereas the whole trouble, including the bundle of parallel slips, may be twenty, forty, or even a hundred feet broad, or more; and, therefore, a cross mine through all the branches must be cut before the coal can be found and levelled by such a mine. When a parallel slip, an oblique slip, and one that cuts right across the strata, meet at certain angles or points, they often produce a triangular piece of coal, of less or greater dimensions, in proportion to the distance these different slips happen to be from one another. Sometimes the sides of these *gussets* of coal are nearly of equal, and sometimes of very unequal lengths. When a great number of these different sorts of slips happen to cut and intersect a field of coal in all directions, they often make sad havoc in it. A proper plan of the fissures and disturbances in such a field would much resemble a large sheet of ice, broken and fallen in, where pieces and fragments are to be seen of all shapes and dimensions, the edges of the fragments being elevated and de-

pressed, or slipt by one another, in all directions, and in all degrees of declivity.

These slips, as well as all other troubles and interruptions met with in working coals, are justly regarded as most serious evils incident to the practice of colliery; and it must be confessed that they are so, and that they often prove exceedingly embarrassing and expensive: and, moreover, they certainly are the most frequent interruption of the regularity of the strata; but it is perhaps the only coal trouble by which we reap any benefit. Contrary to what is generally imagined, a very obvious advantage to coal-mining arises from these slips. They are often a general good when they prove a partial evil. By throwing the strata of coal up and down this way and that, they are spread wider over the face of a country; and the slips throw more of them up, so near the surface of the ground as to be within our reach, than we could otherwise possibly get at, were the strata to keep the same uniform and invariable stretch, bearing, and declivity, without any interruption or breach of regularity.—A parallel slip especially gives us the same field of coal over and over again, as often as it it thrown down by a slip of that sort.—One parallel slip, if it throw the coal sixty or eighty fathoms down, or as much as you can reach with your level or engine, gives you the same field of coal twice over in any given length upon the longitudinal

line of bearing. Three parallel slips, in like manner, give the same field exactly three times over, and so on to any number, provided that there is a sufficient distance betwixt each slip, from crop to dip, to give an ample breast of coal; and the other sorts of slips have in some degree the same effect of keeping the coals floating near the surface, within our reach, which makes the slips a public good, when in fact they often prove a private evil.

When a great slip has many branches, or when there are many slips running parallel and near to one another, they often prove very troublesome and expensive. I have seen some of these very wide, and the metals betwixt each of the branches, being generally imperfect and tender, and dipping confusedly every way, make it difficult to get over them.

Sometimes the coal seems to floor regularly between the divisions of these great slips; but the compartments are so small, that although the coal should be found at full thickness, yet it is cut off again when we have advanced a few feet, or at most a few yards forwards in it. The coal is sometimes found pretty good between the grains of these troubles, and pretty regular, with the proper dip and rise; but it is much oftener found irregular, imperfect, soft, and useless.

When the coal is thrown forty or fifty fathoms off its former level, by a slip composed of several

parallel divisions, which cut across the strata, it often alters the declivity, so that the coal shall lie much flatter upon the one side than the other of this trouble; in which case it is very difficult to calculate exactly how much the coal is thrown off the former level, and how far it is thrown to the right or left out of the former line of bearing. Where the superficies of the strata is seen in rivulets, glens, and other places, where the surface of the earth is broken, some imperfect notices may be obtained, if we are master of the history of the strata of the field; but if the surface is unbroken, and the strata covered with clay or sand, &c. the most skilful are in the dark until they have made trials by boring or otherwise.

The facility with which boring is now performed by men of skill in that branch of business, with a good apparatus, is of great consequence to set us right in such difficult and doubtful cases, at a moderate expence. Before boring was brought to such perfection, and became common, many expensive blunders were committed; and so there are still, when that wise precaution is neglected. It is no uncommon incident in the history of collieries to hear of sinking expensive pits, and sometimes of erecting steam-engines, where they had no coal to work when they got down, because they unfortunately happened to place their pits between two slips which were pretty close to one another, and ran parallel to one an-

other. The metals, or different strata which they cut through in sinking such pits, perhaps might appear to lie fair, and to dip and rise regularly; but when they come to drive mines in the coal, in order to open it up for working in form, they find, when it is too late, that they have no coal of any consequence to work upon. They are soon cut off by troubles on each hand, and all their expence and time are lost, which might have been prevented had they duly examined their field by boring.

I have already hinted, that some of the great slips have many parallel branches; between which branches, or parallel slips, the metals are imperfect, and in the greatest confusion and disorder. There are other great slips that throw the coal forty, sixty, or eighty fathoms up or down at once, that is, at one slip, without any parallel branches in that place. When these are known, they are generally more easily conquered than such as are composed of many branches, because the metals are generally good and regular immediately upon the other side of the single slips; but when many slips run near to one another, the confusion and trouble continue, and produce great embarrassment. The single slips, or steps, for they are known by both names, are of various degrees of magnitude, from sixty or eighty fathoms, or more, down to a few feet, and even a few inches. When these slips are small ones, they are called *hitches*

by Scotch colliers. It frequently happens that a small hitch cuts off only a part of the coal, the other part of the thickness of the seam continuing still in sight. In this case the worst consequence generally is, that the coal is shaken, tender and foul, and continues so until you are quite clear of such trouble. If one of these small slips or hitches should not throw the coal above three or four inches off its ordinary level, yet nevertheless it will very sensibly affect the coal seam, and all the metals about it, as this trifling slip cuts through them all; and they are always in a less or greater degree soft, tender, and brittle upon both sides of the fissure; for which cause the colliers are generally obliged to contract their boards, or rooms, much narrower when they pass through one of these hitches, in order to save the roof, until they are quite clear of it. These smaller slips are very frequent near the superficies of the strata, and much more so in some coal fields than in others. But the small hitches found at the surface seldom go far down; whereas the larger slips continue from the surface down, as deep as we sink, and cut through every individual stratum in their course.

There is yet one material remark to be made concerning slips, namely, that all of them are not always equal in every part of the work; that is, all slips do not always throw the coal and concomitant strata an equal number of feet, or fathoms,

off its former level in all parts of the same work. Some of them are very considerable slips near the surface, or crop of the strata, and throw the coal, &c. a great many fathoms off its former regular floor, or bed, which prove but small ones further down, towards the dip; and, on the contrary, some are great slips to the dip, and small ones near the crop. I have seen many of these that threw the coal several fathoms up or down near the crop, which grew less and less as we wrought down towards the dip, until they at last dwindled away to nothing, and were no more seen: And I have seen very considerable slips pretty far down towards the dip, which grew less and less as we advanced upwards, and at last dwindled away, and were no more seen, before they reached the crop.

I believe it may be observed in general, that the slips which vary so much between the crop and dip of the coal, are commonly such as cut the strata across, either in a right or a diagonal direction. The parallel slips, I am persuaded, are generally more regular, that is, they continue to a greater length, along the bearing of the strata, to be a slip of so many fathoms as we found them at any given point.

It is exceedingly difficult to explain all the phenomena of every particular slip which are met with in working coal, because they all differ from one another in some manner or degree.

All the slips found in the coal metals are mi-

neral veins, and of that species of veins which are called by naturalists *perpendicular fissures*, and by miners, *rake veins;* and as these veins are softer or harder, wider or closer, between the sides, so are the slips *. Some of the slips are very wide betwixt the two sides of the fissure, and the cavity often contains heterogeneous or adventitious matter, frequently such as inclines to be soft and argillaceous; and the sides of such wide slips are generally soft, loose, and dangerous, as they cannot be mined either along or across the slip without securing the mine with timber. Other slips are hard and close, at least in some places upon the longitudinal line of them; and though the strata may be thrown a great many fathoms off the ordinary level by them, yet the two sides of the vein, or fissure of the slip, will be found in some places perfectly close together, though the fissure or joint will always be discernible to a skilful eye.

Again, some of the slips contain between the sides of the fissure several species of heterogeneous matter of a harder nature; such as pyrites, several kinds of spar and crystallizations, and sometimes lead ore, &c. I have frequently seen py-

* I have explained this subject more fully in Part II. where I treat of the natural history of Mineral Veins, to which I refer the reader.—AUTHOR.

rites and large ribs of spar in several slips, and more than once a little lead ore in the collieries of Scotland; but Coalcleugh, in the north of England, is the most remarkable place I know for producing a great quantity of lead in the coal metals. There the lead cut off the coal, or threw it off its regular bed, as other slips do which contain no lead. The coal was found upon the other side of the slip, and wrought as usual, according to my information, and the lead was also wrought with eminent success.

There is a great variety of lesser *troubles*, or disturbances of the regularity of the strata, such as *hitches*, *skews*, *backs*, &c. which are more local, in general only affecting one particular spot. These are not easily described, as no two of them are alike, and they are seldom of great extent.

A *hitch* is a small slip, which only throws part of the thickness of the coal off its former level, and the other part of it always remains in sight, so that the coal is never quite lost with a hitch.

Skews and *backs* are only local joints of an irregular curved figure, which often resemble hitches when we first meet with them, but they only strike out a little way, and turn in again; that is, some of them describe a segment of a circle of lesser or greater dimensions, and others of them only prove a discontinued joint, which only affects a small part of the coal and the coal roof, &c. but seldom extends to any great distance.

It may be proper to repeat here, for the sake of recollection, that there are two circumstances peculiar to all slips and hitches. First, there is in every one of them a real section, or fissure, right across the beds of the strata; and, secondly, the beds of this section, or cut, are slipt down, so that the seams of coal, and other particular strata, floor lower down upon the one side of the fissure, or section. If the strata lie in a horizontal position, the fissure of the slip will be nearly perpendicular; but if the strata hang with any considerable degree of declivity, the fissure of the slip will be found in a slanting direction; as all these sections generally cut transversely, or nearly right across the bed of the strata. I observed before, that every slip of the coal metals has a *vise*, or trace, which points out to a skilful eye which way the metals are thrown out of their former course, or level; and this vise is generally some imperfect remains of the coal; a soft sooty-like substance, or else some species of clay contained in the joint betwixt the two sides of the fissure of the slip. In an upward slip, the coal begins first to be cut off at the pavement, and so upwards, by degrees, until all the coal is lost, in which case the vise leads up into the roof; and, on the contrary, when it is a down-slip, the coal is first lost at the roof, and so downwards, by degrees, or in a slanting direction, until the coal is quite lost at the pavement; in which case the vise strikes down into the pave-

ment; and this makes the vise of singular use to satisfy us which way the coal is thrown off its former level; and it is a guide to lead us the right way to find it again. Sometimes the roof presses down upon the coal, and cuts off much of its thickness, without any slip or hitch. This, in some places, is of several fathoms extent, but in others it is not broader than a few feet or inches. In some places, without any apparent cause, the coal turns foul, and mixed with stone or clay, so as to be good for little or nothing, to a less or greater extent.

II. The second great interruption of the regularity of the strata, and trouble met with in working coal, is a *dyke*. Dykes are very commonly found in many coal-works, and they are of various kinds; such as, 1*st*, Dykes of basaltes, or other hard stone, which are commonly called *whin dykes*: 2*d*, Dykes of imperfect stone: 3*d*, Dykes of clay; in some of which the clay is chiefly of a homogeneous quality, and in others it is mixed with gingle, gravel, &c.: 4*th*, Dykes of gingle and of gravel, without any mixture of clay: And, 5*th*, Dykes of sand.

I suppose that this species of coal-trouble was first called *dyke* from the resemblance of some of the lesser hard ones to a stone wall, or stone dyke, some of them being no thicker than a common garden wall; however, these dykes vary greatly

in thickness as well as in quality, and the matter of which they are composed. They vary in thickness from two or three inches up to a great many fathoms; nay, in some instances, the thickness is too great to be pierced through with a mine; in which case the miner is obliged to abandon the present pits, and to search for the coal upon the other side. But these immense dykes are not frequently met with.

A dyke, in the natural history of the superficies of the globe, may be called a crack, fissure, or chasm in the strata; the cavity of which is commonly filled up with heterogeneous matter, which appears to have been carried there by water, and poured in when the substance of which the dyke is composed was in a fluid state.

Some dykes of *whin*, and of other stones, are so hard that every inch of them, in driving a mine, must be blasted with powder. Besides these dykes of compact and indurated rock, there are others which are composed of softer and more imperfect stone, sometimes resembling fragments of the neighbouring strata packed into the cavity betwixt the sides of the chasm; and others are composed of an indigested mass of imperfect stony matter. There are some of the hard stone dykes found pretty dry, even at a considerable depth below ground, and others are full of open cracks and cutters, and some of them have a longitudinal fissure in the middle of the dyke; these often let down

a considerable quantity of water. The dykes composed of fragments of imperfect strata, resembling some of the coal metals, are seldom very dry.

The *clay dykes*, both the homogeneous and the compounded, are generally very dry; but, on the contrary, the gingle, gravel, and sandy dykes, always, at considerable depths, produce a great quantity of water, and especially below level, in flat and plain situations. At the same time, it may be of use to remark, that if one of these gingle or gravel dykes, or any others composed of open loose materials, happen to cross a glen, or dingle, or to point towards any low river, it may happen to drain the coal, and render the field dry and accessible as low down as that river or valley.

Dykes do not throw the coal seams and other strata off their former levels like the slips; but, on the contrary, when a dyke is pierced through with a mine, the coal is commonly found upon the the same level as where it was lost upon the other side. There are indeed some dykes which throw the coal, &c. a little off the former level, and these I will, for distinction's sake, call *slip-dykes*. These slip-dykes differ nothing in appearance, or in any point of description, from the others which leave the coal upon the same level, but that they throw it less or more off the same level *.

* It would appear that the Author's observation, with regard to the phenomena of dykes, has been limited to their ef-

Dykes appear variously when you strike them first. Sometimes the coal continues good and clean, until it is entirely cut off by a wall of stone, that meets the collier full in the face. At other times, that is, in other dykes, they meet with foul coal several feet, and in some places even several fathoms, before they touch the dyke. The foul coal upon the face of a dyke is plentifully mixed with sand, and other particles of stony matter, which renders it unfit for use. This is called in some places burnt coal, the quantity of which upon the face of the dyke varies greatly in different places. I have seen above four fathoms upon both sides between the clean coal and the stone dyke. There is no vise or joint in the dyke to lead them through it to the coal upon the other side, as in the slip; on the contrary, a solid body of stone meets them in the face, which exhibits no manner of vestige or leader whatever, to point out which way the coal is gone; and therefore they are obliged to drive a mine through a dyke at all adventures, without being able so much as to guess at the thickness of it, until they find the coal upon the other side. However, when they have once

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fects in particular spots; for it is well known, that the strata which they traverse, especially when dykes are of considerable magnitude, are thrown a great way off the level. See a farther account of the natural history of Dykes in Appendix to Part I.—EDITOR.

pierced a dyke by driving a mine through it, they have then a near guess what it will be when they meet with it in another part of the field.

Some of the stone dykes are so hard, as I hinted before, that a mine in them can only be made with the help of gun-powder; and others, on the contrary, are so soft, and the stone they cut through so tender and rotten, that every foot of the mine must be lined or supported with timber. Thin dykes, which do not spoil the coal much, are commonly easy to be got over; but it is generally a work of much time and expence to pierce through some of the greater dykes; and, as I observed before, some of them are so very thick that they prove an insurmountable barrier, so as to oblige them to search for the coal upon the other side.

The clay dykes are generally pretty easily pierced, but the mines driven in the clay are not always so easily secured. It is often exceedingly difficult to drive a mine through some of the gingle, gravel, and sand dykes, and especially at a considerable depth below level, as they then contain a great deal of water, which disturbs and retards the progress of the miners.

III. A *gall* or *gash* is very frequently met with in coal-works. A gash is a crack or chasm in the coal, and in the concomitant strata above and below the coal. These galls or gashes vary greatly from

one another in magnitude, and in their mischievous effects. Some of them prove only to be a small chasm or crack, which does little more harm than by making brittle a small quantity of the coal upon both sides of the gash. These are soon got over, the coal being always found upon the same, or nearly upon the same level on both sides of the trouble; but, on the contrary, many of the wider gashes prove very troublesome and expensive.

The chasms or fissures between the sides of the larger gashes are generally filled with sand, gravel, clay, and other loose matter, which will run down upon the workmen, and choke up the mine they are pushing through, if they neglect to secure every inch of it with timber as they advance; for if it once begins to run, it may prove difficult to stop it, and it may bring such a press or weight upon the mine, that they may not be able to secure it afterwards; and, therefore, the best way is to take it in time, and to secure it with timber, step by step, as they advance, and to set their timber strong and close, as circumstances may require.

In some coal fields they meet with gashes so wide (filled with sand, clay, and other loose matter), that the colliers call them sand dykes.—These are often very wet and difficult to cross, and sometimes altogether impracticable.

These gashes, and the dykes described above,

are so like to one another in many instances of approach, that some of them are hardly distinguishable; are to be investigated upon the same theory in many respects; and seem to me to have originated from the same natural cause: *viz.* a crack or section in a line across the strata, such as we see in miniature in brick-makers clay, spread out, and left too long in the the sun; and these chasms being afterwards filled up with heterogeneous matter poured in from the surface. This foreign matter, so poured in, is the real dyke, which separates the edges of the coal and other strata, from top to bottom, where they are broken asunder by such chasm or fissure; so that the only material difference which I can find between a dyke and a gash is, that the foreign matter which fills up the chasm of the dyke is in some indurated, in others only dried to different degrees, whereas it always continues loose and generally very wet in the gashes.

In some coal fields, several dykes run parallel to one another. Sometimes they are found to be two or three hundred fathoms asunder, but often much nearer, the field of coal being divided by them into so many compartments, and each of the compartments between the several dykes and gashes being subject to be disturbed and subdivided by slips, shakes, &c.

IV. Another formidable, and often a very dan-

gerous interruption to their progress under ground in working coals, is a *shake* in the metals or strata, which affects the seams of coal, and all the other strata above and below the coal. The shakes also vary considerably from one another, both in kind and degree. In some shakes, the coal and the other strata are only shaken, cracked, and broken to pieces, spoiled and made soft, tender, and useless, but remain at or pretty near their former thickness and position. These are commonly pretty easily got the better of, being seldom of great extent. The worst and most dangerous shakes are of two sorts, which, for distinction sake, I will call the *waving* and the *twisted*.

In the *waving shake*, the strata are not entirely broken and separated by a fissure or chasm, as in the slips and gashes, &c. but only shaken, cracked, and thrown into great confusion. When the coal enters into one of the waving shakes, it is seldom or never altogether lost, but it is always rendered useless,—commonly very soft, tender, and shattery,—sometimes thicker, sometimes thinner,—generally waving up and down, yet preserving nearly the same stretch, bearing, and declivity. Some of these shakes do not continue long before the coal comes in, and floors again in its usual regularity and perfection; in other places they prove very wide and extensive, even up to several hundred yards, so as to make it necessary to look for

the coal quite beyond them, and to open up the works of new.

Some shakes only crush and spoil the coal, make it tender and bad, but do not alter the thickness, nor the bearing and declivity of it; and it generally happens that this sort of shake only continues a few fathoms; in which case, the common method is, to drive two or more narrow mines through it, until they come into good and firm coal upon the other side, and then to winn or open out the works of new.

The *twisted shake* is often more dangerous in its consequences than the *waving*, being sometimes (I do not say always) occasioned by a total interruption of the course or bearing of the coal metals, where the coal, and all the other strata of the coal-field, are entirely cut off by another range of strata, which are altogether foreign to the coal. This happens at the extremity of the coal country, both in the longitudinal line of bearing, and upon both sides where other strata commence, entirely of a different quality from the coal metals. But this is not always the case. There are frequently twisted shakes to be seen in the middle of the coal-field. It is very difficult to describe a twisted shake, as it exhibits the utmost confusion imaginable, in all the extremes, from the regularity of the strata. The strata, or metals, in some parts of a twisted shake, appear waved and distorted several ways,—bent round to various segments of a circle,—dip-

ging this way and that in confusion and disorder; fragments of the coal and other strata appear in nests here and there, without continuity, or any other vestige by which to trace out the coal; so that when a large shake of this sort is met with in the middle of a coal-field, the best expedient is to look for the coal upon the other side of it, where the metals are found to floor, and stretch again fair and regular.

But all the twisted shakes are not so formidable. They are found in all degrees like other coal troubles; some of the smaller sort can be got the better of without much expence of time or money, and without quitting the present pits, and some of them only continue a few feet.

CHAP. III.

STRATA OF COAL, AND THE ACCOMPANYING STRATA IN DIFFERENT PLACES, PARTICULARLY DESCRIBED.

I SHALL here point out a few of the many places in the Lothians where the surface of the strata may be particularly examined; where may be seen strata of coal, and its concomitant strata, both above and below, and likewise strata of ball-iron-stone, which is now become an article of much value and consequence in Scotland.

The vertical or edge seams of Gilmerton and Loanhead are the nearest coals to Edinburgh, of any that have been yet discovered and wrought.

The superficies of several of these seams of coal, and of their concomitant strata, are to be seen when the tide is out, within flood mark, between Edinburgh and Musselburgh, near Duddingston fire-engine; and there is a pretty good section of them to be seen in the high road (upon the left hand) from Edinburgh to Dalkeith, betwixt the parks of Drum and Edmondstone *. But the best

* Since writing the above, these sections are concealed by a stone wall, and the ground is levelled and planted.—AUTHOR.

sections of these coals, and of the strata which accompany them, are to be found and seen in the levels and cross-cut mines in the coal-works of Gilmerton.

The rivers North and South Esk, in Mid-Lothian, cut through a remarkably rich coal-field. These two rivers join into one before they reach Musselburgh, where the united Esk falls into the tide. Though the two Esks are but small rivers, yet they have in many places scooped out very deep channels; and there are many fine sections of the strata of coal metals to be seen in the deep ravines upon their banks.

There are good and regular horizontal strata of the coal metals, and of post-freestone, to be seen in the bed, and upon the banks of the river Esk in several places, below the junction of the two branches of it, particularly near the corn-mills of Cowpits colliery, where some pretty good sections are to be seen in quarries upon both sides of the river, dipping towards the north and north-west, with an easy slope.

There are several sections of the flat or horizontal coal metals, a little way above the ford of the North Esk upon the Newbattle road from Edinburgh, and likewise below the ford near the iron mills.

Between Roslin and Auchindinny bridge, there are several fine and lofty sections of the strata of coal metals upon both sides of the river, among

which there are several thick beds of red and white post-stone, with a variety of such other strata as commonly attend coal; and there is a considerable number of coal seams both above and below these sections, many of which have been, and continue to be wrought. The sections of the strata in this part of the river lie flat or horizontal; and in some places these flat-lying strata dip a little towards the south-east, and in other places towards the north-east. This diversity and opposition of dip or declivity are occasioned by the waving of the strata up and down, which is a very common incident where the strata lie very flat, or nearly level with the horizon. In a quarry about a quarter of a mile above Roslin, and also near Auchindinny, upon the north side of the river, there is to be seen a regular continuous seam of coal, only about one or one and a half inch thick, with very strong thick beds of post-stone above it; and I know that there are several thick seams of coal both above and below this thin one, some of which are now working.

There is also a variety of strata lying in various positions between Auchindinny and Pennycuick. About two hundred yards above Auchindinny bridge, in the bed of the river, we see the vertical and the horizontal strata in the same place, the edge metals occupying the north, and the flat ones the south side of the bed of the river. This spot deserves the examination of the curious, as it de-

termines the place and manner of their coming in contact in this part of the country.

Some of the foundations of the cotton mill at Pennycuick, and of the water courses, are cut pretty deep in horizontal coal metals. Here a regular seam or stratum of coal is cut through, about twelve or fourteen inches thick, which is to be seen betwixt the east end of the highest building and the bed of the river.

There is a variety of instructive particulars relating to this subject in the lands of Pennycuick, between the village of Pennycuick and the lands of Newhall: And there are various sections of the flat, and likewise of the edge coal metals in the river, and in the rivulets in the lands of Newhall and Carlops. The horizontal coal strata lie so very flat in this place, and especially in the farm of Carlops, that the coal seams frequently wave up and down, which occasions several gently swelling ridges and troughs, or elevations and depressions, of the horizontal stretch of the coal and the other strata. This incident is known with certainty, as some of the flat coals have been worked in that farm, where the strata were found thus waving up and down.

It is remarkable, that both the edge and the flat coals, with their several concomitant strata, preserve their parallelism, and the true line of bearing, from the sea, until they reach the lands of Carlops; and there the true line of bearing of the coal

metals ends, and they turn away almost in a right angle towards the south-east, instead of the south-west direction, which was the former line of bearing from the sea to this place.

The edge-coal, and all its concomitant strata, appear, and really are in the utmost disorder and confusion imaginable, when they arrive at the extremity of the true line of bearing in the lands of Carlops, where they have dwindled away almost to nothing, the thickest of the seams of coal being hardly so many inches as they should be feet thick. This confusion of the strata is to be seen distinctly in the banks of the river below the bridge of Carlops.

The horizontal strata may be seen in the bed of the river South Esk, upon the east and south side of the town of Dalkeith, betwixt the Duke of Buccleugh's and the Marquis of Lothian's parks. These strata slope with various degrees of declivity towards the north-west; in some places towards the north, and in others towards the west. There are also considerable sections of the horizontal strata upon both sides of the same river, between Newbattle and Dalhousie; and about a quarter of a mile below Dalhousie bridge, there are some irregular discontinuous imperfect seams of coal. The discontinuity of some irregular beds of coal is an incident which is frequently met with.

Many rocks and strata are to be seen in the main branch of the river between Dalhousie and Tem-

ple, all of them lying in a horizontal position, with various degrees of declivity.

In the neigbourhood of Temple there are various sections of seams of coal, and of their concomitant strata, which appear fair and regular. It is, indeed, but rarely that we meet with a more complete and regular section of the strata of coal than the one to be seen close by the Temple mill, and little more than a hundred yards below the church. This is a fair and clean horizontal section, cut nearly perpendicular, and pretty high, in which at least four different seams of coal may be distinctly seen dipping a very little towards the N. N. E. The strata in the neighbourhood of Temple lie remarkably flat. About a mile above the church, the south branch of the river runs upon a hard stratum of rock for more than a hundred yards in our sight, as upon a smooth pavement, and we see it running upon the same stone below the church. There are several seams of coal to be seen in this branch of the river above Temple church, dipping mostly north, though sometimes the declivity changes, and the strata are found to dip towards the N. W. and also towards the N. E. These changes of declivity are commonly met with among horizontal strata, especially those of the coal metals; and are occasioned by the waving and wheeling of the strata.

The north branch of this river is well worth the inspection of the curious. About a hundred

yards above the bridge, two pretty thick seams of coal; appear and there are various sections of the coals and coal metals to be seen in several places for more than two miles up the river, some of which have been and are now working.

The Salisbury Craigs, near Edinburgh, are well worth the examination of the mineral student. The thick bed of rock at Salisbury Craigs, which was quarried some time ago, is a stratum of basaltes, which is easily known by examining the quality of the stone; and the fact may be further evinced by tracing the stratum to the south side of Arthur's Seat, where the same individual bed of stone will be found regularly formed into columnar basaltes; the columns are distinct, and of considerable length and magnitude. When the examiner has made himself master of the stretch, bearing, and declivity of this particular stratum, he may then proceed to investigate the rest of the strata of Arthur's Seat, which is not an easy task for a beginner, the whole hill being chiefly composed of different irregular thick strata of basaltine rocks, which vary considerably in thickness in different places; a circumstance common to basaltes: And therefore, on account of the difficulty of investigation, I would not advise the mineral student to begin a survey of the strata of this mountain, until he is pretty well advanced in the knowledge of the natural history of strata in general.

When he comes to examine these rocks, he will observe that the whole hill is not entirely composed of basaltes. Thin strata of various species are to be found among those rocks. For instance, several beds of freestone have been quarried deep down upon the south side of Salisbury Craigs; and there are regular thin strata of several kinds to be seen immediately above and below the thick stratum of rock which is properly called Salisbury Craigs.

There is a pretty good section of various thin strata upon the south side of the water of Leith, immediately below the mills, and there are numerous thin strata to be seen in the bed of the river, all the way down below St Bernard's Well. These strata appear pretty fair and regular, dipping with an easy slope towards the N. W. or W. N. W.; but the circumstance which is best worth the inspection of the student in this place, is a couple of whin dykes which traverse the strata. These two dykes are to be seen in the bed of the river, one of them near St Bernard's Well, and the other a little higher up. They run quite across the river, almost at right angles; and these dykes, or ridges of stone, are the more remarkable, that these sort of troubles, or interruptions of the regularity of the strata, are but seldom met with in the Lothians, though common enough in other places.

But although whin dykes are not so commonly found in the Lothian collieries as they are in some

other coal-fields, yet the Lothians are not exempted from them. A large whin dyke passes through the coals, &c. a little below Niddry, where it crosses almost at right angles to the bearing of the strata. Another, still larger, is to be seen emerging from the sea at Cockenzie, where it forms the north side of the little harbour, and then continues its course through the country. And, in like manner, several other very large whin dykes are to be seen as you go farther to the N. E. along the shore, some of which form considerable ridges of rock as they pass through the country, and appear in many places high above the surface of the ground; all of them are distinctly seen to cut the coal metals in a line nearly right across the bearing of the strata.

It may not be improper, however, to remark, that there is one circumstance appertaining to the two whin dykes in the Water of Leith, that is not common to every one of the kind, which is, that each of these two is both a dyke and a slip; that is, the strata which are cut asunder by the dyke, are not here found upon the same level on both sides of the dyke, which happens in most (though not in all) others of the same kind. These dykes, which throw the strata off the ordinary level, may properly enough be called slip-dykes *.

* For a fuller account of the vertical strata or dykes, see Appendix to Part I.

There is a great variety of strata higher up in the river Leith, about Slateford, Collington, Currie, and still farther up, and some pretty good sections.

There are various sections of the strata to be seen upon the banks and in the bed of the river Almond, particularly between the sea and Cramond bridge, and farther up, all the way till within three or four miles from Calder.

There are good sections of the strata in the branch of that river which runs upon the south side of Calder, above the bridge, and especially above the house of Calderhall, and still farther up towards the moors. About half a mile below the south bridge of Calder, there crosses the river a thick stratum of coarse limestone, which contains some lead ore in grains and flowers, blended in the composition of the stone; but it does not appear in such quantity as to be worth working.

A considerable variety of strata is to be seen in the north branches of the river Almond, above Calder, and among them several seams of coal, some of which have been worked; and there are some pretty good sections of coal and the concomitant strata in the branch of that river called Breich.

There is a fine section of two seams of coal, and of the strata accompanying them, to be seen in the freestone quarry upon the east side of the river near Cranston.

The county of Fife is a fertile field for the instruction of such as wish to improve in the knowledge of the natural history of the coal country, as almost all the rivulets in the county exhibit sections of seams of coal and their concomitant strata.

There are many sections of the coal metals to be seen upon both sides of the Forth, above and below Inchkeith.

The river Clyde, and its numerous branches on both sides, cut and intersect an extensive coal country, where a variety of fine sections are to be seen; and there are magnificent sections and romantic scenes in the channel of that river, between Hamilton and Carstairs.

Almost the whole county of Air abounds in coal, and it also abounds in scenes proper for the instruction of the mineral student. All the rivers, and almost all the rivulets of that county, exhibit fine sections of the strata, and particularly the river Air and its several branches.

I have now pointed out a sufficient number of local examples of sections, and of regular strata, and the places where they are to be found in the Lothians, &c. But the coal countries are not the only places where we meet with regular strata. There are, besides, numerous fine and regular

sections to be found in the rivers, and especially upon the shores of the ocean, all round the island of Britain, and particularly round the Highlands and north of Scotland; and of all places in the Highlands and north of Scotland, Caithness is the most remarkable. The sea-coast of Caithness is singular for magnificent, extensive, and lofty sections of remarkably thin and uncommonly regular strata; and though the strata upon the shores in some parts of Galloway, particularly in the stewartry of Kirkcudbright, are regular and lofty, yet they are not generally so thin as those of Caithness.

In both these places, especially upon the south-east coast of Caithness, and in the parish of Colvend in Galloway, the student has an opportunity of seeing regular strata for miles in length, where he will not only observe beds of stone, which exhibit a great variety as to thickness, colour, and other external appearances, lying *stratum super stratum*, as he advances along shore, with various degrees of slope or declivity; but he will also have an opportunity of viewing and of investigating a great many of the troubles, breaks, and irregularities of the strata, such as dykes, slips, shakes, &c.

These extensive and lofty sections, or cliffs, may be called the anatomy of some parts of the mineral kingdom, where the student can see some parts of his subject dissected and laid open for his examination.

Among a great variety of other particulars to be seen in the two districts under review, there are many caves or caverns of different magnitude. Some of these caves are very wide and high; others of them are of middling and of lesser dimensions. Again, some of them are only a large and spacious cavern, at and near the mouth, but are of no longitudinal extent, that is, do not push far in, and others of them push a great way in under the land. It is a remarkable fact, which, in my opinion, deserves to be noticed, that each of these caves or caverns is a real mineral vein; and the most of them, if not all, are real slips in the strata, such as were described above in the coal metals. The most of these are what are called by miners *rake veins*,—by naturalists, perpendicular mineral fissures; and it is a fact which also deserves notice, that a considerable number of these veins in both places, but particularly at Colvend in Galloway, contain copper ore.

The cliffs in many parts of the West Highlands and Isles resemble very much the shores of Caithness and Galloway, and almost every considerable rivulet in several parts of the Highlands has cut through many regular and curious sections of the strata, and many of the Highland mountains exhibit prodigious cliffs or sections of immense height and magnitude. In the Highlands of Scotland the mineral student will meet with

abundance and variety of amusement and instruction.

THOUGH the examples of stratification I have here pointed out, may be deemed a digression, when treating of the natural history of coal, yet it is a piece of necessary information to the mineral student.

CHAP. IV.

OF THE DIFFERENT KINDS OF SECTIONS OF THE STRATA OF COAL; OF STRATIFICATION; AND OF THE THICKNESS OF A SEAM OF COAL AT DIFFERENT DEPTHS.

IN this Chapter, it is proposed, I. To describe the different kinds of sections of the strata; II. To make some observations on stratification; and, III. To inquire, whether a seam of coal preserves at all depths the same thickness.

I. To obtain an accurate knowledge of the strata by examining various sections, it may be proper to throw out a few hints about the different kinds of sections of the strata, and how they are to be distinguished from each other. There appear

to be three different kinds of sections of the strata: 1st, *The level or parallel section*;—2d, *The right-angled section*;—and, 3d, *The oblique or diagonal section.*

1*st*, The level section is one that runs in a line parallel to the bearing of the strata. When we are viewing one of these parallel sections, we see the edges of the several strata lying flat or level before us; and when we face such a section at right angles, so as the right and left hand are equally near the face of the rock, the declivity then is in a right line from the eye across the strata, and the dip is in a right line either down towards the foot, or away from the eye; and if the strata lie very flat, it may sometimes be difficult to know which way the strata decline in such a section, as perhaps no sensible slope appears any way.

2*d*, The right-angled section is one that is cut in a line right across the bearing of the strata, and parallel to the declivity; or, in other words, this section is in a right line from crop to dip. When we face one of these sections, so as to bring the right and left hand equally near to it, then a line drawn straight forward from the eye is a dead level line, which runs parallel to the bearing of the strata. This right-angled section is more instructive than the former; for in this we not only see the various kinds of strata disposed in regular order, *stratum super stratum*, but we also see the degree of slope or declivity of the several strata.

In this section we see the one side or edge of each stratum dipping downwards quite out of our sight, and the other side or edge rising up quite to the day, or to the clay or other cover, if the superficies of the strata happen to be covered in that place.

3*d*, The oblique or diagonal section is more difficult to be explained with precision than either of the former two, because it may be so various, or may run in so many diagonal directions, or collateral lines, across the bearing and declivity; and, therefore, I shall only in general observe, that some of these sections may approach pretty near to the parallel or horizontal section, and yet have a small degree of slope or obliquity, and others may approach pretty near to the right-angled section, and yet not be quite parallel to the declivity, or be in a right line from crop to dip, though near it.

It is to be supposed, that there is a greater number of these oblique or collateral sections than there are of the parallel or right-angled, because all those that are cut in any possible acute or obtuse angle or line between the other two, must come under this denomination or description.

With respect to the first, that is, the *parallel section*, it may be impracticable to determine the degree of slope or declivity of the strata, even with an instrument, because you only see the edges of the several beds of stone, or others, facing you in

level or parallel lines. If it be a fair, regular, and uniform section, perhaps the best rule then for judging of the degree of declivity, especially if the slope be right away from the eye, is to consider the position of the face of the section. If it stand nearly perpendicular, we may generally conclude that the position of the strata is nearly horizontal. If the face of the section lean back with a considerable slope, and the foot of the rock advance forward towards your foot, you may then conclude that the strata decline away from you with a considerable or proportionable degree of slope; as the several transverse fissures, which occasion such regular sections, are generally cut across at right angles to the bed of the strata. If the declivity lean forward towards the eye, you will then see the edges of the strata hang down towards you, and then you can judge of the degree of slope. When the slope is down towards you, such sections generally overhang a little.

With respect to the second, that is, a *right-angled section*, you can take the degree of the declivity of the strata in it at once; for a line stretched from crop to dip along the face of any individual stratum in the section, will be exactly parallel to the slope or declivity of the strata.

But it cannot be so easily determined what is the degree of slope or declivity of the third or *diagonal section*, because the section itself is cut in a collateral line, and it cannot be determined at

once, without examination, how far this line is upon one side or other of the line of bearing, or upon one side or other of the line of declivity; which two lines, that is, the bearing and declivity, form a right angle.

All that I have yet advanced on this subject, relates only to what may be called regularly disposed strata, and to such accidents as locally disturb and break through that regularity.

II. But it may be proper to inquire, whether or not all the rocks which compose the superficies of our globe are regularly stratified, or if there are certain species, classes, or arrangements of rocks, which are always found stratified, and others that are not.

With respect to stratification, the materials which compose the superficies of the globe may be divided into three classes: 1*st*, Such as are always, or at least generally, found regularly stratified; 2*d*, Such as are partly and imperfectly stratified; and 3*d*, Such as are seldom found stratified at all.

Of the first sort are all the coal metals, most of the argillaceous strata, the generality of limestones, and different species of the indurated mountain rocks.

Of the second sort are many of the mountain limestones, which are extremely irregular, both as to the thickness of the stratum, and as to the con-

tinuity of it in the line of bearing; and many of the basaltic rocks so frequently met with in the Lothians, Fife, and other parts of Scotland, are likewise very irregular in thickness and in continuity upon the line of bearing. Both of these are so irregular in this respect, that sometimes they swell out to an enormous thickness; and a little way forward, upon the longitudinal line of bearing, they are found dwindled away almost to nothing; and two or three hundred yards farther forward, still upon the same line, the same individual stratum will swell out again to various degrees of thickness. Many of the mountain limestones exhibit the same irregularity,

Of the third sort are many mountains of granite in the Highlands of Scotland, and many other places. It is no uncommon thing to see granite rocks so perfectly free from any marks of stratification, that there is no difference between a small solid mass of that stone and a mountain, excepting in magnitude, the whole mountain being one prodigious mass of solid stone, without any division of strata.

There are also some other rocks besides the granite mountains which have very little appearance of stratification. Such, for instance, are some little hills of mountain limestone, which we meet with in the Highlands and other places, and likewise little hills of basaltes, which we see forming small islands in the Frith of Forth, in many

parts of the Lothians, Fife, and other parts of Scotland.

Many of the rocks which may be called regularly stratified, have in some places very great imperfections in the strata. Some of these are imperfect in point of continuity; and such either fail entirely, and are lost, in the longitudinal line of bearing, or else turn thinner, or worse in quality, in the same line.

Others are found to resemble a wedge; and such a stratum will be found pretty thick at the surface; but as it goes down towards the dip, it wears thinner and thinner until it comes to an edge, when it soon ends in nothing.

Some, again, are found of a good thickness below, which wear thin as we come upwards, and at last come to a thin edge, and end in nothing, even before they reach the surface.

Some particular strata are found irregular, wear thicker and thinner, and are sometimes entirely lost in advancing upon the longitudinal line of bearing, as well as in going down upon the line of declivity.

Again, there are some strata so imperfect, that they resemble a double wedge; that is, such strata are found irregular, and fail in continuity both ways, and do not stretch so far as the regular strata which accompany them. These are found to be thick in the middle, and to wear thinner and thinner, and end in nothing, as we advance both

ways upon the line of bearing. There are many other instances of imperfect stratification too tedious to be investigated here.

III. I SHALL now inquire, whether a stratum of coal, found but thin at the crop or surface of the ground, will grow to be a thick seam farther down towards the dip?

A seam of coal is found fully as thick in the superficies of the strata as it is farther down. When once a seam of coal is discovered at or near the surface of the ground, if it appear when discovered, or is afterwards by trials brought fairly between regular roof and pavement, it may be taken for granted that it is then at its full thickness, and would not increase, though you should sink twenty fathoms in it.

There are, indeed, particular instances of coals being thicker below than above, and also of their being thicker above than below; but, in general, they are at full thickness when found between roof and pavement.

In an extensive coal-field, a great number and variety of seams of coal are cut through in bringing up levels, in driving cross-cut mines, and in sinking pits. Some of these seams of coal are of very considerable thickness, some are very thin, while others are intermediate between the two extremes of the thickest and the thinnest. Now all these various seams are generally found to be very

near the same thickness above as they are below, when once they are found between solid and regular roof and pavement; and this is necessary in the nature of things, because then the seam of coal is a regular stratum among regular strata, which are disposed above and below it; and, therefore, it should, and in fact it does keep its station full as regularly as any of those found placed above and below it, both in the longitudinal line of bearing, and from crop to dip in the line of declivity. In short, when a seam, whether it be thin or thick, is once found fairly bedded betwixt regular roof and pavement, and is perfectly clean and free from hitches and other troubles, it is then at its full thickness.

Perhaps these assertions may seem to intimate, that all seams of coal are invariably regular in thickness, both in the line of bearing, and likewise in the line of declivity; but I would not wish what I have said to be understood in that light; for there are some circumstances and accidents which alter the case, and occasion the seam to vary considerably in thickness. A seam of coal is frequently found thicker upon one side of a slip than the other, and likewise upon one side of a great dyke than the other. The same may be observed of some of the great shakes and gashes. The same individual seam of coal seldom preserves invariably the same uniform thickness to the extent of four or five miles forward upon the line

of bearing, though it may continue nearly the same within a more limited field of only a mile or two. Great variations in the dip and rise of a coal frequently affect the thickness of the seam; and such changes in the degree of dip or declivity often occur as we advance upon the line of bearing; and when a seam of coal falls suddenly from higher to much lower ground, the thickness of the seam is frequently altered.

Some coals are much more regular and uniform in thickness than others. I have seen many seams continue perfectly regular and equal in thickness for a considerable extent every way, and I have seen other seams so exceedingly variable, that you could not depend upon finding the coal equally thick for twenty yards together in any part of the field, and in some seams you cannot find ten yards of it of equal thickness, particularly when they are disturbed by dykes, slips, gashes, shakes, &c.

Sometimes the roof falls down for a certain space below its ordinary level, and presses the coal, or squeezes it much thinner, especially in the middle of that space. These accidents of the roof pressing down nearer the pavement than it should be, and squeezing the coal below its ordinary thickness, are of various dimensions. Some of them are not above two or three feet in diameter. These lesser ones are like a wart or small protuberance on the under side of the stratum, which is the immediate roof of the coal; and

this protuberance sinks down into the upper side of the seam of coal, like the bottom of a great pot. These protuberances are called by Scotch colliers a *bonnet-case* and a *pot-bottom*.

But all these accidents are not of such small dimensions as the bonnet-case. Some of them are not only two or three feet, but two or three yards diameter, and sometimes even up to thirty or forty yards, and more. I observed that the small ones thrust down suddenly into the upper side of the bed of coal like the bottom of a great pot; but, on the contrary, the large ones generally press down gradually with a gentle swell.

These troubles sometimes squeeze out one third, and at other times one half or more of the thickness of the coal. They are frequently of a roundish figure, and they squeeze out the coal thinnest in the middle of the trouble, which rises gradually higher as it extends from the centre, until the roof comes to its ordinary level, and the coal comes to its ordinary thickness at the outskirts.

But the principal and greatest of all the causes of the variation of the thickness of the coal, appears when the seam approaches the extremity of the coal country, where strata commence of a different quality from the coal metals. The coal metals, and especially the coal seams, always wear thinner and thinner as they approach the outskirts of the coal country, as it may be called; that is, the extreme boundaries of the coals and coal me-

tals. In this case, I have seen seams of five or six feet thick dwindled to so many inches.

THE vulgar error of the *craw-coal*, as it is called in Scotland, frequently proves a dangerous error; and, therefore, I will explain the matter, in order to give a caveat against the pernicious consequences of that notion.

What is meant by the craw-coal, is the crop-coal, or uppermost seam of coal in the field, which is always supposed to be a thin one.

The notion of the craw-coal originated from the false supposition, that in all places where coal is found, a thin seam is uppermost; and that when once a thin seam is found, you are sure to find a thick seam at a moderate depth below the thin one, or craw-coal. This, it is acknowledged, may sometimes happen; and indeed it frequently does happen. We know it by experience, and therefore it cannot be denied. At the same time nothing can be more absurd than to assert that it always happens so. That notion is the child of ignorance and fraud. The ignorant imagine the assertion to be true, because they wish it to be true. It seems to give them a clue to lead them at once through depths of knowledge which they have not yet explored, and they either cannot or will not take the trouble to examine the truth of the position; and the crafty make use of the notion to lead the unwary to incur useless expence.

By observation and experience, we know that the thick and thin seams of coal are blended together in a coal-field; and this fact is established by cutting through a great number and variety of seams in some extensive coal-fields, where we as often find a thick seam uppermost as a thin one, and we as often find a thin seam below as a thick one above.

The truth is, we can form no true notion of the disposition and order of the strata, until we have either cut through them, or have some other opportunity of seeing how they are arranged; and yet the notion of the craw-coal still prevails in many parts of Scotland; for I have often heard those who were making trials for coal say, with a tone of assurance, that they were now certain of coming to a good seam a few fathoms deeper, this being an infallible symptom of a thicker and better seam being near.

But a man of real knowledge and extensive observation, will frankly declare that he knows nothing about the matter, without having experience for his guide. I have frequently seen three or four (and sometimes more) thin seams of coal placed next to one another, neither of which was of sufficient thickness for working; and I have often seen good workable seams lying next to one another, without any thin seams intervening; and I have as often, perhaps oftener, seen thick and thin, and middling seams blended promiscuously.

Indeed they are always so blended, that we know of no order or natural station, or of any thing else relating to them, but what we discover by experience.

Further, it is not only the seams of coal that are thus promiscuously blended together in the coal-field; the various and different coal metals are also mingled together, and with as much uncertainty, as to any rule or order of their stations, as the seams of coal.

There is in most coal-fields a surprising variety of different kinds of strata accompanying the several seams of coal; and of this vast variety, we find strata of every quality, thickness, and colour, so promiscuously blended together, that when we are sinking pits, or driving mines through any of them, the most experienced do not know what is to come next, until they have somehow or other acquired that knowledge by former observation, that is, by seeing the order and disposition of those strata somewhere before.

In our coal-pits and cross-cut mines, and in the rivers and rivulets which have cut and washed the superficies of the strata in our coal-fields, there is abundant demonstration of the truth of the position, that the coal and coal metals are promiscuously blended together, without any certain order to be depended upon as a rule or indication in practice; and moreover, the great variety of strata of different qualities and colours, hard and soft,

thick and thin, which are found to be the immediate roof of the several seams of coal, even in the same field, is another convincing proof of the truth of the position.

Though there should be twenty seams of coal in the same field, it is twenty to one but they shall be found to have twenty different roofs, that is, that stratum, which is the immediate roof of one seam of coal, shall differ from the immediate roof of another seam in quality, colour, and thickness, insomuch that perhaps no two out of the twenty shall be exactly alike.

CHAP. V.

OF THE STRATA IN CONTACT WITH THE STRATA OF COAL.

The several roofs of coal may, in point of hardness, be divided into three different classes.

I will take a cursory view of some of them, and will just touch at their several qualities and colours: I will, therefore, 1*st*, Examine such as may be called *very hard*;—2*d*, Such as may be called *good and firm coal roofs* of middling hardness;—3*d*, Such as may be called *soft roofs* but in respect to the exact thickness of the stratum, with the co-

lour, quality, and degree of hardness, the variety is almost endless.

I. Among those which may be called *very hard roofs* are,

1*st*, Strata of basaltes, commonly called whinstone. Strata of basaltine rocks are very common in many coal-fields in Scotland. There are several thick beds of this stone betwixt the different seams of coal at Borrowstounness, and one of them is the immediate roof of a seam of coal in that ground; and there is a thin seam of coal below a bed of beautiful columnar basaltes at Hillhouse lime-quarry, a mile south of Linlithgow. In the Bathgate hills, south of Linlithgow, there are several strata of coal and several strata of basaltes blended together, *stratum super stratum*.

These instances may suffice as a proof, that strata of basaltes are sometimes the immediate roof and pavement of strata of coal. The several strata of basaltine rocks are always very hard, often very thick, and generally of a black or blackish grey colour; but it is proper for me to remark here, that the basaltine rocks are only known to be such by a very few naturalists. They commonly go by the general name of whin-rocks in most parts of Scotland and the north of England. I think this stone goes by the name of *cockle* among Cornish miners, and it is called *skurdy* in the north of Scotland.

Among the few gentlemen who are acquainted with basaltes, the most of them imagine that the rock should always be found formed into prismatical figures or angular columns: but this is supposing too much; for the truth is, that this rock is only found formed into columnar, or other regular figures, in such places where the rock was originally exposed to the influence of the external air.

As a proof of this assertion, the thick stratum of rock near Edinburgh, called Salisbury Craigs, is only formed into regular columns upon the south side of Arthur's Seat, where it was originally exposed to the atmospherical influence.

Another proof of the above assertion will be found in the stratum of basaltes, which is formed into small and beautiful columns at Hillhouse lime-quarry near Linlithgow, as the same individual stratum will be found not formed at all in several places at a small distance from that quarry *.

The basaltine rock is to be judged of and denominated from its quality and colour and component parts, and not only from the figure it sometimes assumes, which is merely accidental, arising

* This quarry was examined lately by Mr Muirhead, Professor of Natural History in the University of Glasgow; but whatever it might have been in the Author's time, no such appearance could then be observed.—EDITOR.

from situation more than from the quality of the stone. This rock is very common in the coal countries, and in many other parts of Scotland, and it is frequently found formed into glebous, spherical, and other figures, as well as the columnar; but always where it now is, and we have good reason to suppose that it always was, exposed to the external air.

Wherever we trace a stratum of basaltes under the cover of other incumbent rocks, it is not then formed into any regular figure. Wherever we cut through it in sinking coal-pits, we do not find it regularly formed. Wherever the face of a regularly formed basaltine rock is quarried away until it goes under other incumbent rocks, we soon lose the angular figures, and an uniform face of a rock comes in without the least appearance of a prismatical, or any other regular figure.

2*d*, Limestone may be reckoned among the very hard roofs of coal. Strata of limestone of various thickness, quality, and colour, are very common in coal-fields. Sometimes the stratum of lime is the immediate roof of the coal, and sometimes there is a thin argillaceous stratum, or *following clod*, as it is called, found betwixt the stratum of lime and the stratum of coal.

There are several beds of limestone in the coal-field of Gilmerton, near Edinburgh, and some of them are very good, and of considerable thickness.

At Blackburn, in West Lothian, a stratum of limestone, of six or seven feet thick, is the immediate roof of a good seam of fat caking coal, which seam is also about five or six feet thick.

At Carlops, and at Spittlehaugh in Tweeddale, there is a seam of coal immediately below the lime-quarries, which is wrought out to burn the stone.

I have seen lime immediately above coal in a great many places; but these are sufficient instances in point, as the fact is commonly known.

3d, Some of the post-freestones prove very hard roofs of coal. What is commonly called post-stone, is a thick and solid stratum of freestone, out of which blocks or pillars of any size and figure may be cut. Thick strata of post-stone are frequently found to be the immediate roof of seams of coal, without the intervention of a following clod, or any stratum whatever, between them, and sometimes with a following clod, or a thin argillaceous stratum, betwixt the coal and the main roof of post-stone; and the post-roof is frequently rendered very hard, by being intersected with foul ribs, or mixed throughout with ferruginous matter, or iron pyrites.

4th, Thinner strata of freestone are commonly found in most coal-fields to be the immediate roof of coal; and some of these, as well as the post-stones, are rendered very hard by admixtures of ferruginous and sulphureous matter.

5th, What are called *dogger-bands* by Scotch colliers, are frequently found to be the immediate roof of coal. Some call strata of iron-stone dogger-bands, and the ball iron-stone they call doggers, as well as masses of the pyrites in many of the Scotch collieries; but besides the strata of iron-stone, there is also another species of coal roof frequently met with, which is called a dogger-band. This dogger-band is an imperfect stone, composed of several heterogeneous mixtures, among which pyrites bears a considerable proportion, which so effectually binds and connects the whole together, that it is sometimes very difficult to break through it. This species of dogger-band is sometimes much thicker than the strata of iron-stone. Both the sorts are well known to be very hard, and to be frequently found immediately above the coal.

6th, There are in many coal-fields several strata of whin-stone, properly so called, which is not basaltes. Some of these are of considerable thickness, and others not above two or three feet thick; and they are of various colours, such as black, a blackish and lighter grey, brown, red, &c. These strata of whin-stone are always very hard, and they are frequently the immediate roof of coal.

II. THERE are a great many good and substantial roofs of coal, which yet are easy to work, and of moderate hardness. Among these I will reckon,

1*st*, Post-stone of a kindly quality, which is not impregnated with ferruginous matter, or any other heterogeneous mixture which hardens the stone too much, and makes it cross and difficult to be cut.

2*d*, Regular strata of freestone of various colours, textures, and degrees of thickness; but none of which are so thick as to deserve to be called post-stone.

The thinner strata of sandstone, or freestone, are perhaps the most numerous of all stones in most coal-fields, and they are so frequently found to be the immediate roof of coal, that it would be superfluous to say any more about them; only it may be noted, that some of these regular strata of clean and pure sandstones are not above three or four feet thick, and others not above three or four inches; and they are often found of all degrees of thickness between these two extremes.

3*d*, Grey bands, or grey-coloured freestone bands, are likewise commonly found to be the immediate roof of many seams of coal, and these may be reckoned among those of moderate hardness. These grey bands, or grey thin strata of imperfect freestone, are very numerous in coal-fields, and there is generally a great number of them arranged together in the same place, lying immediately above one another; and they are found from one inch up to twenty inches thick, though

the most common thickness is from two to six inches. These thin grey strata are called by Scotch colliers *grey fekes* as well as grey bands. They are often found moderately hard, and of a strong texture, so as frequently to make good flags and covers for sewers. When there is a considerable number of these together, they commonly make a very good and safe coal roof, as they generally have a considerable degree of strength and cohesion, especially when the ingredients in the composition of the stone, which give it the blackish or grey cast, partake of the nature of the coal; but when the black admixture partakes of the blaes, or black tilly argillaceous matter, then the grey bands are more weak and fragile.

4*th*, Hard, strong, and well stratified blaes may be reckoned among the coal roofs of moderate strength and hardness. Strata of blaes, or shale, are very common and exceedingly numerous in coal countries. They are always black, or of a bluish black or a black grey colour, and there is nothing more commonly the immediate roof of coal. Some of the strong and hard blaes are perfectly black, or of a greyish black; and some of these strata, of different shades of the black colour, are found to be from about a foot and a half to two or three inches thick: the medium thickness of the strata of the best blae roofs is from one foot to three or four inches.

Some of this sort of blaes is so strong as to make

a very good and safe coal roof, but it is rare to find any of it so hard as not to be easily cut through in sinking. All blaes seem to have a considerable quantity of a black argillaceous matter in the composition of the stone, and these strong blaes appear to contain a considerable quantity of sand; and they are also impregnated with a certain portion of an inflammable oil, and sometimes they partake of the real coal itself, in such quantity as to be sometimes visibly seen.

In some places the thinnest of these strata are found to be the immediate coal roof, and in other places the thickest; and again, in other different places, those of all the degrees of medium thickness.

There is as great a variety in the quantity of these blaes found together immediately above different coals as there is in the thickness of the particular strata. In some pits we do not find above five or six inches of blaes immediately upon the coal; in other pits, we find five or six fathoms, and in some particular places even much more.

5th, Whitish and ash-coloured argillaceous strata, of middling strength and thickness, are in many places found to be the immediate roof of coal.

Some of these light-coloured argillaceous coal roofs are pretty thick, others of them are thin and of middling thickness, like all the other coal roofs of pretty equal strength and hardness. I have

seen some of these two feet thick, and others of them not above two inches. There are a great many coal roofs of this colour, and much of the same quality, which, from their brittleness, are very dangerous. At the same time, many of them prove very good roofs, owing either to some peculiar ingredient in the composition, or to a more perfect contexture and formation of the strata.

6th, Streaked coal roofs of middling strength and hardness. These streaked roofs are of two sorts: *First*, such as are composed chiefly of sand, with a very small mixture of clay and blaes; and, *second*, such as are composed chiefly of clay or blaes, with a very small mixture of sand. Some of these exhibit larger, and others smaller streaks or ribs. I have frequently seen some of these stones so finely streaked as to resemble the most beautiful striped cotton stuffs.

The stripes or streaks lie exactly parallel to each other, and exactly parallel to the bed of the stone, and are always spread out the whole breadth of the stratum. The colour of these stripes is various in different strata. Some are nearly black and white, others white and red, and yellow and red; while in others the stripes appear of a lighter and a darker grey colour.

Some of the finely striped stones exhibit streaks less than a quarter of an inch. It is very common to see stripes about a quarter, and between that and three quarters of an inch; but in these

finely stratified and finely striped stones, it is not common to find streaks of a full inch thick, without some different shade in one side or other of the stripe. The stratification of these striped stones is generally as perfect and regular as can be imagined.

The second sort of striped coal roofs, that is, such as are chiefly composed of blaes, with a smaller mixture of sand, differs but little from the first in appearance; only the colours are not always so bright, the stripes are not so fine, nor is the roof quite so hard as the sandstone striped roof.

III. Of the soft coal roofs, of which there is a great number, varying with respect to quality, colour, and thickness, I will point out a few, and I shall begin with such as are of a black, a bluish black, and a black grey colour. Some of these are regularly stratified, others but imperfectly, and others not stratified at all. All these soft black and blackish coal roofs are by the Scotch colliers, and those of the north of England, called by the general name of *blae*, or *till*.

1*st*, There are arrangements or classes of regularly stratified blaes found as the immediate roof of different coals of a great variety of thickness, from three or four inches up to a good many fathoms; but of the particular thickness of each stratum of those I call *regularly stratified*, I have

seldom seen any one of them much above a foot and a half, or at most two feet thick; but I have frequently seen great numbers of them not above two or three inches, and some of them not much above one inch thick, even where there was in all a considerable thickness of blaes, consisting of a great number of strata arranged together. Some of these tender roofs of regularly stratified blaes have an oily appearance externally, and through all the fissures and joints of the strata; that is, they appear smooth and glossy, and are very slippery to the touch. Others of them have nothing of this; but whether oily or not, these soft blaes make but an indifferent roof, at best, for they are always weak and brittle.

2*d*, The second sort of soft coal roof which I am to mention, is blaes imperfectly stratified. This sort of roof is in every respect the same in quality and colour as the last, the only difference between them being in the different degrees of stratification. This sort appears irregularly stratified: the strata or beds are not perfect, but unequal and lumpish, which makes it a bad and dangerous roof; for the inequality and various joints of the strata occasion their falling down in large masses or lumps when the coal is wasted from under them. Some of these irregular strata of blaes appear in thick, and others in thin and middling beds; and some of these, as well as the last mentioned, have a greasy or oily smoothness, from which

they are called by Scotch colliers *creeshy* (greasy) *blaes*. This oily smoothness makes these irregular strata particularly troublesome and dangerous in a coal roof; for, being full of joints and natural divisions, which run in every direction, the oil runs through all the joints, and occasions this sort of blaes to slip and fall out so soon as the coal is worked away from under them.

Some of these glossy greasy blaes have such a quantity of the natural oil as to make them flame a little in the fire; and there is in some places a considerable quantity of the hard stratified blaes mentioned above, which will not only flame in a fire, but some of it will actually burn when fire is set to it, though it will not consume. There is a species of pretty hard stratified blaes at Pitfirran in Fifeshire, which burns so well, that if a small fire is once kindled at one corner of a hillock, it will burn throughout; but it is no less in bulk after than before it was burnt, nor does it produce any ashes. This blae is of a black colour before it is burnt, but the fire converts it to a pale red, in which it is so far from consuming, that it acquires a considerable degree of hardness in the fire, which renders it good stuff for roads, particularly for horse and foot paths. It appears pretty evident, that this blae contains a portion of natural oil in the composition of the stone, as it burns, but does not consume; for if it partook of the coal matter in such quantity as to make it in-

flammable, part of the coal would be seen; and moreover, part of the blae would consume, and produce ashes, which is actually the case when a blae has such a quantity of coal in its composition as to make it in any degree inflammable.

3*d*, Of soft blaes, which are not stratified at all, there is only one stratum or bed in the same place, without the intervention of other strata above and below it. This species of blaes is as commonly found to be the immediate roof of coal as any thing else I know; and the beds of it are found of various degrees of thickness, from two or three inches up to two or three fathoms: But whether the stratum of it be found thick or thin, the whole stratum is always one uniform mass, without divisions into distinct strata. But it should be remarked, that all these unstratified beds of soft blaes are not equally of one uniform mass throughout the whole stratum. Some beds are divided into small angular masses in the stratum, and others into larger angular masses or glebes; but whether these soft blaes are found glebous or uniform through the whole stratum, they always prove a bad and troublesome coal roof.

These black argillaceous strata of the coal-field are by many called beds of till. The uniform sort is called *dauk*, and the glebous sort is called blaes, or, by Scotch colliers, *lipey blaes*. Both the uniform and the glebous soft blaes frequently contain ball iron-stone; and indeed the regular con-

tinuous strata of iron-stone are commonly found in stratified soft blaes.

There is, besides, another variety of soft coal roofs of a grey colour, of which some are regularly stratified, and some are not.

4th, Of regularly stratified soft grey coal roofs there are several sorts. The first of these which I will take notice of is the soft grey bands or grey *fekes*, which have a considerable quantity of sand in the composition of the strata.

Many of these soft grey bands are as regularly stratified as any coal metals whatever, and some of them are found in very thin strata; but whether thick or thin, they are so weak and tender as to make a very bad and troublesome coal roof. Many of these grey bands look pretty well at first, but they soon fail and come down when undermined and exposed to the influence of the air; and I suppose that this is owing partly to there being too great a quantity of clay in the composition of the stone, and partly to the want of a sufficient quantity of natural cement to connect the several particles of the stone together and promote induration.

5th, The soft grey regular strata, or grey bands of an argillaceous kind, vary greatly in colour and thickness. Some of these are of a dark, and others of a lighter grey, and some of them exhibit pretty thick, and others thin strata. These soft grey argillaceous strata are very numerous in most coal-

fields, and they are frequently found to be the immediate roof of the coal; and these, as well as the black kinds, are found in all quantities or degrees of thickness above different coals, from a few inches up to several fathoms; but whether there is much or little of it together, and whether these strata are thick or thin, this sort is generally found to be a weak and brittle roof.

6th, The soft grey argillaceous bands, imperfectly stratified, differ little from the last in quality or colour, the only difference being in the different degrees of stratification. Many of the last mentioned sort are as finely stratified as can be imagined, that is, the strata are generally thin and of middling thickness, and perfectly regular, finely spread out, and every part of each stratum equally thick; but, on the contrary, this sort, though it has the appearance of strata, yet the stratification is but clumsy and irregular, that is, the several beds are unequal, and divided by many irregular joints into unequal masses, which makes this sort a bad and troublesome coal roof; as the masses separate at the joints, and fall down when the coal is wrought out.

7th, Soft grey argillaceous beds of metal or coal roofs not stratified at all; and this, as well as the black sort described above in the third division of soft roofs, is of two kinds or varieties, viz. *first*, such as is found broken or formed in the stratum into glebes or masses; and, *second*, such as is found

in one uniform mass throughout the whole bed, without any division into strata. I need not repeat that these grey soft roofs are of all degrees of thickness; but in other respects, there is to be observed little difference, excepting in the colour. Here it may be proper to add, that ball or glebous iron-stone is frequently found in this as well as in the black unstratified blaes, and that both in the glebous and uniform beds; and strata of iron-stone are also found in the stratified soft grey blaes.

8th, White and ash-coloured soft argillaceous coal roofs present, of all others, the greatest variety. Of this sort of roof, some are regularly stratified, some imperfectly, and others not at all. Of the whitish argillaceous roofs, some are a compound of a gritty sand and clay, others appear to be chiefly composed of pure clay, and some of a loamy clay.

I will begin with such as are regularly stratified and mixed with sand; and of this sort some strata are mixed with sharp and gritty, and some with softer sand. What has been said above with respect to the variety of thickness of the several strata, and of the several parcels or arrangements of those strata into beds of various thickness, may be said of the white as well as of the black and grey argillaceous coal roofs, and therefore need not be repeated. Many of this sort of gritty or sandy clay roofs are very soft, weak, and brittle.

9*th*, The next whitish argillaceous soft roof I shall take notice of, is such as we find regularly stratified, and of a homogeneous quality, or not mixed with sand. Some of these are very finely and perfectly stratified, and they are found of different degrees of hardness; but, in general, they prove but a weak and tender coal roof. This sort is not all equally well stratified. Some are found in irregular strata, and with all the other imperfections and varieties mentioned before.

10*th*, White and ash-coloured argillaceous coal roofs, not stratified at all, afford a very great variety. Sometimes we find very thick beds of white and whitish argillaceous matter in the coal-fields; and some of these, as well as of the black soft roofs, rise in glebes and masses of different sizes, and others are uniform and homogeneous throughout the whole bed, whatever may be its thickness; and these, as well as the black, are found of every degree of thickness. Some of these beds of white argillaceous marl-like matter are found to be a sandy or loamy clay, and others are of a pure homogeneous clay, which does not feel gritty between the fingers or in the mouth; on the contrary, the matter of some of these fine white clay roofs possesses a saponaceous property. The shades and varieties of colour in this sort are as numerous as in the last mentioned. All the clay roofs of a homogeneous uniform structure, what-

ever be their colour, are called *dauk* by Scotch colliers.

THE general species and the several varieties pointed out, and described above, may be considered as a pretty full selection of the most common roofs of coal; but it must be considered only as a selection, and as a very brief account of some of them. The different strata of the coal metals found in different coal-fields, are so numerous and so various, that it would take a large volume to enumerate and describe them all: I can only pretend to give a general history of some of them; and therefore I shall only further observe here, that what I have said above about the coal roof is equally applicable to the pavement of the coal, as in fact we find as great a variety of strata below different seams of coal as above them.

Having taken a view of the various strata which accompany coal, I should now proceed to point out the strata of the mountain rocks, that is, such other strata as do not commonly accompany coal, in order to distinguish them from the coal metals; but this subject will be discussed in Part Third.

CHAP. VI.

OF THE DIFFERENT DECLIVITIES OF THE STRATA OF COAL.

It has been observed, that the general course or bearing of the strata in this island is nearly from north-east to south-west; but this is so far from being a fixed rule that may always be depended on, especially with respect to the coal metals, that we can never presume to know which way they trend, or which way they dip, until we see some of them. Those strata which decline from the horizon with a considerable degree of slope, are generally found to be more constant to the line of bearing, than such as lie much nearer the horizontal position. The reason of this is obvious. When strata lie very flat, or nearly parallel with the horizon, they frequently vary from the ordinary line of bearing, being more subject to waving and wheeling.

We shall now endeavour to point out the real cause of the deviations from the general bearing. Let us then suppose, that the coal metals or strata in any field lie pretty flat, or nearly parallel to the horizon; that the strata in that field trend in general towards the south-west; and that the gene-

ral dip or declivity of the strata in that field is towards the south-east, and the rise towards the north-west, which is in a right line across the bearing. Now, so long as those strata continue to have exactly the same degree of slope, they will also continue to have exactly the same line of bearing; but where the strata are very flat, this perfect regularity seldom stretches a great way in any line, because the strata which are nearly flat in any particular place, are very often found to fall perfectly flat a little way forward upon the line of bearing, we may suppose at the distance of half a mile; and when they fall quite parallel to the horizon, they very often fall over the horizontal position line, and so acquire for some space a different dip, or line of declivity, from what they had before; and very probably they also trend in a different line from the former for the same space or distance. Let us, in further illustration of this subject, suppose, that the strata are perfectly flat and level with the horizon at any fixed point, as, for instance, in a particular inclosure of so many acres, which is bounded by its own fences; and that when you advance forward out of this inclosure into the next, with your face towards the south-west, the strata then begin by degrees to fall from their level horizontal position, and to dip towards the south-west. In this case the line of declivity is towards the south-west, which was the line of bearing before the strata fell quite flat.

Now, when the line of declivity is towards the south-west, the bearing of course must be in a line from north-west to south-east, as the line of bearing and the line of declivity always cross each other at right angles. In these cases of the strata flattening, and of their dipping towards another point, it constantly happens that this change of dip is only local, and continues but for a limited space or distance, though the precise distance cannot be determined until we discover it by observation or experience. But we may suppose that they continue to dip towards the south-west, with an easy slope, for about a quarter of a mile; and when the strata arrive at that point, they generally fall perfectly flat again, and continue so for a limited space, without any sensible dip in any direction; and at the extremity of this space the strata begin to rise gradually towards the south-west, with an easy acclivity, and then the line of declivity is towards the north-east.

At present they rise towards the south-west. A little farther forward in that line, the strata arrive at the height of that acclivity, flatten upon the height for a limited space; and still farther forward, they gradually begin to dip again towards the south-west, and so on perhaps for many times over again. This is what I call the *waving* of the strata; and in fact the strata in this case resemble, upon a large scale, the waves of the ocean in a calm day after a storm.

When the strata fall quite flat, or perfectly parallel to the horizon; between these great waves, of consequence they must then spread over a much greater extent of country than before, while they dipped towards the south-east; and as the true line of declivity is supposed to be towards the south-east, when the strata fall quite flat, then they must stretch away and spread out far towards the north-west, a great way beyond the former line or limits of the superficies of the strata; and this I call the *wheeling* of the strata: and in fact, when in this position, they frequently do stretch far beyond the former limits of the superficies or crop of the strata, and fetch a great compass over an extent of country, sometimes of miles north-west of the former crop or outburst. When the horizontal strata, from dipping a little towards the south-east, fall quite flat, they sometimes do not stop there, but fall over; that is, the north-west side of that class or range of strata falls quite over the horizontal level, and dips for some distance towards the north-west, which occasions the strata to stretch still farther towards that point, than if they only fell quite flat or parallel to the horizon. The truth is, when once the strata come to a horizontal flatness, they are often found, while they continue near that position, to lean and dip this way and that, without the least regard to the true line of bearing or declivity.

While the strata continue in this horizontal po-

sition, they are sometimes found equally flat, that is, to continue upon a level plane for a considerable extent of ground; but more frequently they are only found to be flat in general with respect to their spreading over an extensive country: But with respect to different particular spots or compartments of that country, they are found to lean irregularly in various directions; sometimes forming ridges and troughs, and sometimes a bason. A bason is formed in the horizontal strata, when, to a certain extent, they fall lowest in the middle, and rise gradually all round towards the extremities, in the form of a piece of hollow ground in a meadow, which contains a lake of stagnant water in a rainy season; and to form this bason in flat seams of coal, it must be understood that the strata dip inward all round towards a common centre, and of course there must be an acclivity or rise of the strata from that centre towards the outskirts of the bason. It cannot be supposed that these basons dip regularly towards the centre as from the circumference of a perfect circle; some, however, come so near it, that the eye cannot determine, without examining circumstances, which is the shortest, or which the longest diameter of the circle. Some of the basons are not a quarter of a mile in diameter before the seam of coal and other strata stretch away in a different position, while the diameter of others exceeds a mile; and it generally happens, that in these large basons the coal dips

and rises so slowly and gradually, that in some parts it is scarcely perceptible.

When these local declinations of the flat-lying strata happen to be upon a large scale, it makes smooth work in carrying on a colliery, because you advance a great way before any sensible change of the dip and rise takes place to affect and disturb the plan of working; but, on the contrary, when the waving and wheeling of the strata are upon a small scale, the sudden changes of the dip and rise frequently occasion much trouble and expence. As, for instance, the narrower or smaller a trough is, it generally happens that the coal and other strata dip down the more precipitately, in proportion to the small dimensions of the trough; and of consequence it is more difficult to work down a sudden precipitate slope than a gradual easy slope, especially if there is much water in the mine. The same difficulty occurs when we meet with high and narrow ridges between troughs. We may ascend the nearest side of one of these ridges, and work away over the top or highest part of it very well; but when we begin to descend on the opposite side, we immediately find water, and perhaps cannot proceed until we go back to the lowest place, and bring up a level mine under the pavement of the coal, quite through the ridge, in order to level the coal upon the other side of it, for the purpose of carrying off the water. By some Scotch colliers this is called a *ridge*, by

others a *hirst*, and by others a *sow's back;* but all the hollow parts in the coal are called *troughs*, whether they be in the form of trough or bason. The coal is sometimes found thinner than ordinary upon the top of a sow's back or a narrow ridge; but when the waving of the strata is so gradual as to make the dip and rise scarcely perceptible, the thickness is but seldom affected, either on the ridge or in the troughs.

But these ridges are in some places upon so large a scale, that the waves of water do not convey an adequate idea of the spacious dimensions of the troughs, and of the extent and magnitude of the ridges. Every body must have seen long and low mountains or ridges of rising ground running parallel to one another, with valleys of moderate extent or breadth interposed between them. In some places, the waving of the strata is upon so large a scale as to resemble those parallel ridges and valleys which diversify the face of the country.

Let it not be imagined that all this bustle about the waving and wheeling, and other various declinations of the coal metals, is the work of fancy, intended merely to amuse the ignorant. It is a fact well known to all who are acquainted with the natural history of the strata; the fact is obvious to the accurate observer, and it may be established by numerous local examples. The horizontal coals which are worked in Midlothian in Scot-

land, all round Dalkeith, are found to wave considerably in several places, particularly towards the parishes of Carington and Temple, and towards the west, in the parish of Linton in Tweeddale; some of these coals have been worked in the lands of Carlops through several troughs, and over several ridges.

The coal which has been mostly worked out in the farm of Carlops, so far as could be done with adits or levels, is found in this waving order, that is, in ridges and troughs; and the variation of the dip and rise there generally consists of gentle easy swelling waves. I know, too, that the coal is whole and unwrought in the bottom of some of the troughs there, because it could not be drained by the old levels; and, moreover, it is known to several coal-masters, that the splenty coal and others, which are wrought to the south-west of Dalkeith, across and under the rivers North and South Esk, ascend the north side of the hill or rising ground to the south of Dalkeith, cross the height of that hill by Blackside, &c. and then descend to the south side of the hill, and cross the valley by Oxenford and Cranston, and are actually seen and wrought upon the south side of the valley and river at Cranston; so that here they are found to wave, or to rise and fall, upon a large scale, the extent of the ground now mentioned being about five miles in a line from Lasswade, which is situated a little westward of Dalkeith,

to the farthest place where these coals have been worked, upon the south side of the river at Cranston. In this line the splent-coal, &c. has been worked, and is now working by John Clerk, Esq. of Eldin,—by the Marquis of Lothian in several places south of Dalkeith,—by Sir John Dalrymple at Blackside, and also upon both sides of the river at Cranston. Other examples might be produced; but these are sufficient to show the fact, and to confirm the doctrine of the waving of the strata.

From this investigation of the waving and wheeling of the horizontal strata of coal, it is obvious at first sight, that this variation from the same line of bearing and declivity, is so far from deserving to be reckoned in general among ordinary troubles and irregularities, that in fact, instead of being a nuisance, it becomes a great benefit. Their falling very flat, and sometimes falling quite over the horizontal level, and dipping the contrary way, and their waving up and down, as described, distributes the same individual stratum, or the same number of strata of coal, over a much greater extent of country than if they preserved invariably the same degree of declivity, and the same line of bearing. Their falling sometimes quite flat, and declining this way and that, in the variety of positions described, preserve the strata of coal near the surface, and within our reach, over an extensive country; by which means we can, at a moderate expence, work ten times more of them.

In some instances, perhaps, we can work twenty times more than if they dipped towards the centre with an uniform and invariable slope; for if the line of declivity were invariable, however easy and gradual the slope might be, they would too soon be quite out of our reach. But matters are much better disposed; for by means of the parallel slips described above, which throw the same coals many times up nearer the surface, we have the same seams of coal many times over again; and, by means of this waving and floating of the coal near the surface, we have a much greater extent in our power than we could have by any uniformity of the strata. There is an instance of this at Pitfirran in Fife, where the coal dips towards various points of the compass; and in consequence, I believe, ten times the quantity has been wrought that could have been done with one uniform line of bearing and declivity.

Before I leave this topic, I should observe, that although the coal and coal metals are found sometimes to fall from different degrees of declivity to a horizontal flatness, and while they continue near that position, that they wave and wheel, and vary the slope and bearing, and so float and spread near the surface over an extent of country, yet it must not be understood that they always continue in this waving position. In some coal fields the strata acquire this horizontal and waving position, and afterwards, farther towards

the south-west or towards the north-east, the declivity becomes again so steep as to form an angle of forty-five degrees, and in some particular instances to approach still nearer to the vertical position. There are also some instances in which they do not recover the former regular bearing and declivity, but continue to wave and wheel to the extremity of the limits of the coal-field, especially towards the south-west. We have an example of this in the horizontal coal metals of Midlothian, which never recover a regular, uniform, and continued line of bearing and declivity, after they once begin to wave, until they arrive at the extreme boundary of the coal metals towards the south-west.

There is yet another circumstance to be noticed here. It appears that the strata of coal, and their concomitants, sometimes vary from the true line of bearing considerably, by falling to the horizontal position, and by waving and wheeling, &c.; and in this case the true line of bearing ceases to be the dead level line; for any change in the degree, or in the line of declivity, changes it: yet it generally happens, nevertheless, that there really is coal still in the true line of bearing all the way to the extreme boundary of the coal-field, although that line ceases to be the dead level line; and, therefore, it cannot be determined without experience, at what depth the coal is to be found. The true line of bearing, or what may be called the

bearing of the strata, in general, through the Island of Britain, is nearly from north-east to south-west. When this line is lost in any particular place in a coal field, by the flattening and waving of the strata, it enlarges the coal field in breadth; but it does not follow that the coal is lost in any part of the line.

CHAP. VII.

RELATIVE DECLIVITY OF THE STRATA OF COAL TO THE INCLINATION OF THE SURFACE.

It is imagined by many that the coal below resembles the figure of the surface of the ground above; and perhaps the observations now made about the various changes of declivity in horizontal strata, and the instances adduced in proof of that variety, may be considered as a confirmation of that opinion. If the notion were true, that the disposition of the strata below ground resembles the figure of the surface above, I apprehend that the observation might be so improved as to be of great utility in practice. Upon this supposition, when we see an uniformly regular surface, we might expect that the subterranean geography

would also be regular. When we see a wavy country, which gently swells into broad ridges, and sinks into hollow valleys, we might then expect that the strata would likewise wave up and down; and when we meet with a rugged broken surface, we should be led to expect the same irregularity below ground.

This hypothesis may appear at first sight at least plausible, and there may be instances found where the dip and rise of the strata appear to confirm it; but these instances are so few, that whoever shall depend upon always finding this correspondence, will be frequently disappointed. Great irregularity and disorder are often observed beneath a regular unbroken level surface; and, on the contrary, strata are found remarkably plain and regular underneath a rugged unequal broken surface. In some few places, we see the strata for a little way dip and rise with the surface of the ground; but this in general is only for a short distance. It is no rule to be trusted, for we find them oftener dipping into the hill, against the rise of the surface of the ground, and across it in a right and in a diagonal direction, and to all points, without regard to the figure or quality of the surface.

I have in some places seen low hills in coal countries which swelled to a round or oval figure, with an easy ascent upon all sides, in which the strata appeared to dip and rise almost all round, nearly with the same slope as the surface of the

ground; and, on the contrary, in other little hills of the same figure, I have seen the strata dipping into the hill upon all sides, so that each stratum on such little hill formed the figure of a bason, and all the strata in the hill formed a nest or pile of basons within one another; but these are uncommon instances, and only to be seen in a very few places.

The declivity of the coal metals is so variable, both in respect to the degree of slope, and to the point towards which they dip, that we have no sure rule which will guide us every where to judge of it but observation and experience; for we find them as often dipping against the slope of the ground as with it. Sometimes we find the strata in a coal country running parallel to the side of a hill, or ridge of ground, and we as often find them crossing such a hill in a right and in a diagonal line.

The coal, limestone, and other strata, run almost right across the Bathgate hills in West Lothian, and almost right across the high and low grounds contiguous to those hills upon both sides; and although the coals and other strata climb quite over the high ground to the south of Dalkeith, and across the low grounds at Cranston, as already noticed, yet this has more relation to the waving of the strata than to the waving of the surface of the ground.

As a proof of this assertion, the strata run nearly right across the Bathgate hills, and the valleys and high grounds upon both sides, from the south

side of the Forth, until they cross the river Breich, south-west of Midcalder; yet it is to be observed, that the strata of coal, limestone, and others, in those high and low grounds, decline sometimes towards the west, and sometimes towards the east, which must be owing to the waving of the strata, for they do not incline with the surface of the ground. The ridges and valleys here run nearly east and west, but the bearing of the strata is nearly north and south; and whether the strata dip to the west or to the east, the same line of bearing towards the south is still continued; and of consequence the difference of dip or declivity of the strata must be occasioned by their waving up and down, without any regard to the figure of the strata.

In all my observations, which have been pretty extensive, I never yet found that the external figure of the surface regulated the position of the strata; and therefore I infer, that wherever the coal and other strata below, are found to dip and rise as the surface of the ground does above, it is merely accidental: for even in the instance above mentioned to the south of Dalkeith, where the strata pass under the valleys, and climb over the high grounds, yet even there they are far from dipping and rising every where with the surface of the ground; on the contrary, the rise and declivity of the strata are found to be different from the slope of the surface in several places, which

must be owing to the waving of the strata, and to their various degrees of declivity.

I have dwelt the longer upon this part of my subject, and have taken pains thoroughly to search it out, with a view to obviate the mistaken notion which many entertain of the coal strata preserving one continued line of bearing invariably, and to set people on their guard against the consequences of such a mistaken notion.

From all my observations and experience, I may safely draw this general conclusion, and lay it down as a rule, namely, that we can place no dependence upon the bearing and declivity of the strata, at any considerable distance out of our sight and knowledge, and more especially the horizontal strata, because they are often thrown out of the course of both, by waving and wheeling, and by dykes, slips, &c. which ought to make people more cautious than they often are in proceeding with expensive operations in sinking for coal at hazard, from a confident persuasion of its running invariably upon one line of bearing through th whole length of a country.

In many places, the horizontal strata are observed varying the line of bearing by falling flat; and then dipping towards various points different from the former line of declivity, and by these means spreading abroad over a great extent of country, out of the former line of bearing; from which I infer, that if they are thus liable to be di-

verted out of the former line of bearing, we ought not to risk too much upon an uncertainty. There are more chances of the coals being turned off the line of bearing than of their continuing in it at any considerable distance; and as there are means of ascertaining the point, we should be well assured of coal before we launch into expensive trials for it.

With respect to such strata of coal as have a great degree of slope, it may be observed of them in general, that they are more regular in the lines of bearing and declivity than the horizontal strata. When the line of declivity of a seam of coal, with its concomitant strata, approaches the angle of forty-five degrees, or a few degrees above or below that angle, the strata are found to be much more regular in their declivity and bearing than when they are very flat.

In some coal countries we find classes or arrangements of coal seams, with their concomitant strata, dipping down with so much precipitation as to be denominated *edge-seams;* and sometimes, in the same neighbourhood, we shall have another class of coals, &c. lying very flat, and both of these running parallel to one another. We have an instance of this in the edge-coal seams of Gilmerton, &c. near Edinburgh, and of the flat coals to the south of them. These we shall treat of in the next Chapter.

CHAP. VIII.

OF THE EDGE-COAL SEAMS OF MIDLOTHIAN, AND OF THE FLAT BROAD SEAMS TO THE SOUTHWARD.

THE edge-seams, it has been observed, are in general much more regular in their bearing and declivity than such as are very flat. In tracing the course of edge-seams backward and forward upon the line of bearing, I have frequently seen them vary considerably in the degree of declivity, so as in some places to become nearly, and even altogether, as flat as some of the horizontal coals which in Scotland are denominated *flat broad coals;* and, in other places, I have seen them turned up quite on edge, or into a vertical position. There is an instance of both these variations to be seen in the edge-coal and coal metals to the south of Edinburgh. This arrangement of the coals, with the concomitant strata, trends away from the south side of the Forth by Duddingston, Niddry, Edmondston, Gilmerton, Loanhead, and other places. There are more than sixty seams of these edge-coals, of various thickness; and in some places in their course there are more than twenty of them workable.

This class of coal-seams, with their concomitant strata, dips towards the south-east, and rises towards the north-west; and of consequence the bearing, or dead level line, is towards the south-west. These coals and their concomitant strata extend from the sea at Duddingston, for about sixteen miles south-west upon the same line of bearing, where they turn away at a right angle towards the south-east; and in many places upon this line, the strata in general are very regular. These coals are called *edge-seams*, because they dip precipitately with a very great slope. The general degree of declivity is about forty-five degrees from the horizon. In some places they stand higher, that is, more upright, and in other places lower; but the medium dip is about forty-five, or at most forty-seven degrees.

There are but few places in Scotland where a class of coals and coal metals can be traced so far in a straight line, which naturally infers, that these coals stretch very regularly in the true line of bearing, and consequently that the declivity is likewise very regular; as in fact the regularity of these two lines, when applied to seams of coal, is mutual. But notwithstanding the remarkable regularity of the bearing and declivity of these coals in general for so long a stretch, there are in some places considerable deviations from both. At the Bank, betwixt Edmondstone and Niddry, about two miles south-west from the sea, these strata are found

perfectly in a vertical position. In proof of this, coal-pits of considerable depth have been sunk in a seam of coal, from top to bottom, without going out of the coal the whole depth, either into the roof, which is upon one side, or into the pavement, which is upon the other side of the pit.

I hinted before, that the superficies of a considerable number of these strata is cut in the side of the high road from Edinburgh to Dalkeith, near Edmondstone, where they likewise appear to stand in a vertical position; this place is about half a mile south-west from the Bank. At Gilmerton, which is more than a mile south-west from the Bank, the greatest number of the edge-seams decline about forty-five degrees. Some of these coals are pretty near to one another, and others of them are farther asunder; but the northernmost of all the seams which have been worked is much farther off than any of the rest; that is, there is a much greater distance betwixt this seam and the next workable coal to the south of it, than there is betwixt any other two seams in the whole field; and as they still flatten by degrees, the farther north we advance, this coal, which is called the *North-green seam*, is considerably flatter than the rest, especially towards the north-east end of the coal field, which is about a mile long upon the bearing of the coal. In the south-west end of this field, the North-green seam stands as much on edge as the rest of the coals. About the middle of the

field it is somewhat flatter than any of them, and in the north-east end it is considerably flatter, and, of consequence, the seam stretches farther out towards the north-west. In one place near the north-east end of that field, this coal first falls quite flat, and afterwards falls quite over, so as to dip towards the north-west, which is diametrically opposite to the real true dip or line of declivity, which is towards the south-east; and the North-green seam continues in this north-west declivity a considerable way over the ordinary line of the crop of this coal.

This tongue of the North-green seam is about half a mile broad, but it stretches away towards the north-west more than half a mile over the ordinary line of bearing. The coal and other strata in this place fall over in a kind of trough, so that the middle of the tongue is by far the deepest part of it; and it rises and crops out upon both sides, that is, towards the south-west and towards the north-east, so that there is a dip or declivity from both these sides towards the middle of the trough, and the middle of the trough dips away towards the north-west.

Perhaps I may not be perfectly understood in describing these different dips; but at Gilmerton near Edinburgh, a lime-quarry lies below this coal, and is wrought upon both sides of the tongue; and as the quarry dips and rises just as the coal does, the various declivities mentioned may be

easily traced out. This lime-quarry is worked under ground, by leaving pillars to support the rock above, and is easily accessible for investigation.

Slips in edge-seams throw them more to one side than up and down. There is a large slip about the middle of the coal field at Gilmerton, which throws the coal upon the west side of the slip about one hundred and sixty yards farther south than it is upon the east side of it. At first sight, this may appear as a deviation from the true line of bearing, but I reckon very little upon such a slip, because another slip may throw the coal as far to the north as this has thrown it to the south.

These variations in the lines of the bearing and declivity of the edge-seams are sufficient to show, that there is perhaps no such thing as a long stretch of the strata of coal in a straight line without some deviations, and yet these run in as straight a line as any in the country. But there are other deviations from the true line of the bearing of edge-metals, and such as have a considerable degree of slope, besides the two instances now mentioned. Sometimes they bend like an elbow, and then run in another direction from the former line of bearing. Thus, supposing the line of bearing to be south-west, as you advance along this line, you come to a place where the strata bend backward, and turn away to the west, and sometimes towards the north-west. But

the strata in these deviations do not always bend backwards. They sometimes turn the contrary way, and from a south-west direction come to point towards the south, and even towards the south-east. These bendings in the line of bearing of the edge-coals are exceedingly various. Sometimes they only bend a little either towards the west or towards the south, with an angle so obtuse that it is scarcely discernible at first sight, and sometimes they take a quicker and more sensible turn; and again, they are not all alike in respect to the manner of turning. In some of them the strata come about with a gentle, easy bend or sweep, and in others they turn shorter, either with an obtuse or a right angle; and after these turns, the strata bear away towards the new point which they have gained by the turn sometimes to a considerable distance; but it is not common for them to stretch very far upon this new course before they turn again and come into their former line. When these traverses in the line of the bearing of the strata are short, that is, when there is but a short distance between the several angles or turnings, it would be exceedingly difficult to work such seams of coal.

Upon the sea-shores, and in other places where the strata were laid bare, some of these traverses or angles are observed so near to one another, that it would be impracticable to work coal in them, the strata in that case being too much distorted

and broken by being so often turned and twisted; but when there is a considerable distance between each turn or angle, the strata are generally as perfect between the turns as in any other place, and in that case coals may be wrought very well. The edge-seams of Gilmerton and Loanhead, &c. have some of these bendings in the line of bearing, and that both backward and forward; that is, in some places they bend a little backward, or towards the west, and in other places they bend a little forward, so as to point more towards the south than before: But there is no turn in these strata between Duddingston and Carlops so considerable as to approach to a right angle.

Much might be said about the inferior and the superior strata of coal; and it may perhaps be found, that the inferior coals have a greater degree of slope, and are more regular in the line of bearing, than the superior coals; and, on the contrary, that the superior strata of coals are generally more flat and horizontal than the inferior; and that they more frequently wave up and down, and float near the surface over the face of the coal countries.

But as this part of the natural history of the strata of coal leads into abstruse disquisitions, and as the thought is but new to me, having had as yet neither time nor opportunities of investigating circumstances, with a view to ascertain the fact, I must leave it to be examined by others.

All that I can say to it just now is, that there

are classes or arrangements of edge-coals, with their concomitant strata, at Gilmerton, &c. to the south of Edinburgh; and there is a number of flat seams of coal, with their concomitant strata, lying to the south of the edge-seams, and running parallel to them, all the way from the sea-shore near Musselburgh, as far up the country as the edge-seams stretch in the line of bearing, which is about sixteen miles.

I have in several places seen the line of contact, where the south side of the edge-metals join to the north side of the flat metals or strata; and in other places where I have seen them join, both the edge and the flat strata appear in full perfection; that is, they are both of them firm and good, without confusion or disorder; the flat metals are immediately flat, and the edge-metals are immediately on edge, where they come in contact with each other.

It is supposed by some, that the edge-seams stretch away under the flat coals, and also under the valley at Dalkeith, and that they rise up again about five or six miles to the south-east of Gilmerton, &c. where they begin to dip down precipitately towards the south-east. It must be confessed that this hypothesis is very plausible, but to me it is very doubtful; and, therefore, I will leave it as a doubt, although I have good reasons to suspect that the edge-seams do not rise again from under the flat coal towards the south-east.

CHAP. IX.

OF THE EXTENT OF COAL FIELDS AND COAL COUNTRIES.

The next question relating to the history of coal, which falls naturally to be examined, is the extent of coal fields or coal countries.

Many are of opinion that the strata of coal keep their course in general in the line of bearing quite through the island, and perhaps round the globe.

It has been asserted by men of great knowledge and of sound judgment, that the coal and coal metals stretch away under the mountains, and emerge again upon the other side, and keep their course, or trend, in general to a certain point. This was once my own opinion; but when I began to entertain doubts on the subject, I resolved to investigate every circumstance connected with this point. In order to which, I carefully examined several places in distant parts of the country, where the coal metals end and the mountain rocks begin, in expectation of seeing the coals and coal metals thrown down, and the other classes of different strata lying above them; but I never could observe any symptoms of this being the case in

any one place I examined: on the contrary, I every where saw the clearest demonstration of the coal and coal metals being uppermost, and of the other different strata pushing in below them. In several places the coal metals, where they approached the side of a hill, or any other place where different foreign strata commenced, discovered great irregularity; and when they came in contact with the foreign strata, the coals and coal metals were evidently thrown up, and in the highest degree of confusion and imperfection imaginable, so that the coal appeared to be no better than dross or soot, and the hardest stones among the concomitant strata no better than rubbish or sand; whereas, on the contrary, the new or foreign class of strata emerged from under this confused imperfect mass in full perfection of quality and regularity of strata. In some places where the seams of coal and their concomitant strata approached the outskirts or extremity of the coal country, I have seen the coal seams first begin to grow thin and troubled, even at a considerable distance, and then, as they advanced nearer the extremity, grow more and more troubled and distorted, and at last, when they arrived at the extremity, the coal seams of several feet thick diminished to so many inches; and the coals, with their concomitant strata, forced round, quite out of their natural course, so as to cross the true line of bearing at right angles, but in the highest confusion imaginable, and entirely useless;

whereas, on the contrary, the different strata which succeeded the coal metals, were perfectly regular and good, and stretched away, in the true line of bearing, to that point to which the coal metals trended before they were thrown out of the ground and lost their course.

Now, it is impossible to have a clearer proof than this of the extremity of a coal field. I have seen this change commence in low situations, at several miles distance from any mountains or hills, in the true and real line of bearing, both of the coal metals and of other different strata; and I have seen still lower ground farther forward in the same line, after the new strata commenced, than where the change took place; and in this lower ground the new range of strata appeared in a great many places, keeping the same regular course or line of bearing which the coals and coal metals had lost.

As local examples are most convincing in such disquisitions, I will give a remarkable instance of this not far from Edinburgh, which may be examined by mineral students; and after a thorough investigation, it will afford a clear and satisfactory proof of what has been advanced.

I have already mentioned and described the edge-coals to the south of Edinburgh, and shown that the north-east end of this class of coals, with the concomitant strata, appears first in our sight upon the sea-shore at Easter Duddingston. From

thence the strata trend towards the south-west by Gilmerton and other places for about sixteen miles; and there is not perhaps one quarter of a mile of the whole sixteen where these coals have not either been wrought, or else are to be seen crossing the rivulets which run down from the Pentland hills right across the superficies of these strata.

Many of these seams of coal are either now working or have been wrought at Duddingston, Niddry, the Bank, Edmondston, Drum, Gilmerton, Melvill-Moor, Loanhead, Dryden, Greenlaw, Cooking-Parks, Pennycuik, and Newhall. These places are set down in the order of their situation as we advance from Duddingston towards the south-west; and Newhall, which is the last mentioned, is at least sixteen miles from Duddingston. The lands of Newhall are about two miles long upon the line of bearing, that is, from north-east to south-west. The edge-coals are seen in perfection about the middle of those lands, only, that the greatest number of the seams are thinner here than farther east; and at the mansion-house of Newhall, which is a little farther south-west than the middle of the ground, some of the edge-seams were wrought, but were found in considerable disorder; and less than half a mile farther south-west than the house of Newhall, these coals arrive at the utmost boundary of the coal field in the line of bearing. The bridge of Carlops over

the North Esk, is about half a mile westward from the house of Newhall; and about a hundred yards below this bridge, the river begins to run across the superficies of the coal strata in a diagonal direction. The banks of the river in that place are very high, and the strata of coal and coal metals are seen distinctly on both sides, as well as in the bed of the river. The north bank of the river, upon the Newhall side, is much higher than the south or Carlops side; and on the north side we see many of the seams of coal and their concomitant strata in great disorder and confusion.

In some parts of the north bank of the river, the strongest post-stone and the soft coal metals are twisted and blended together; and in other parts of the bank, where something like strata are to be seen, both the coals and their concomitant strata have been so squeezed and twisted, as to be rendered entirely useless. About eight or ten miles farther north-east, some of these seams of coal are six, seven, or eight feet thick, and one of them, called the great seam, is in some places about fourteen feet thick; but where these capital seams of fine coal cross the Esk betwixt Newhall and Carlops, there is not one of them that is regularly one foot thick; the most of them being only four or five inches. But besides this confusion and disorder, the strata are squeezed together into much less room in the line across the strata; and, moreover, they are turned from the south-west to a southerly

direction. About a quarter of a mile farther forward, towards the south, they complete the turn to a right angle; that is, the course is changed from a south-west to a south-east line of bearing.

The river Esk issues from the Pentland hills, immediately at the bridge of Carlops; and it is remarkable, that the rocky base of the south side of those hills comes down close to the river side, immediately below the bridge, and continues close to it for about three hundred yards farther down; and in that very place the south-west line of the edge-metals, which is the true line of bearing, glances in a slanting direction against the base of the hills.

Now, if the coals really immerged and passed away under the mountains, we should certainly lose sight of the edge-seams in this place; but the fact is, that we do not lose sight of them: On the contrary, we see them distinctly rising up and cropping out, instead of being immersed under the hills; and, moreover, we evidently see that the outbursts or crops are squeezed and distorted, and thrown into endless confusion, where they come in contact with the base of the hills; and we also see the crops of them turn away towards the south and south-east, in a right angle to the former line of bearing. All this is as evident as ocular demonstration can make it.

I have already observed, that there are horizontal coals, with their concomitant strata, imme-

diately upon the south side of the edge-coals; and that these flat coals run parallel to the edge-coals all the way from the shore of the Forth, as far to the south-west as this class of strata are found to stretch. Some of these flat coals are found in the lands of Carlops in their proper situation, parallel to the edge-coals; however, they go no farther in the line of bearing. But these, as well as the edge-coals, are also found to crop out towards the south-west, or former line of bearing, and the crops of them likewise turn away gradually to the southward, with a gentle sweep round, until they at last gain a south-east direction; but it is observable, that these flat coals are not thrown into such confusion and disorder at the turn and extremity of the field as the edge-coals, because they are at some distance from the base of the Pentland hills, which come in contact with the edge-metals, and disturb them, throwing them out of their true course, a little before they arrive at the extreme boundary of the coal-field.

Now, the fact of the flat metals turning from a south-west to a south-east direction, may be shown in two different ways.

First, the crops of the flat coals, and of the limestones which accompany them, are seen and wrought in several places upon the turn, and after they have gained a south-east direction; and, secondly, other rocks of quite a different quality are seen in a great number of places in lower ground,

in the former or south-west line of bearing, viz. in the river Line, and several other places round the village of Linton, and in a great number of places over a large extent of country to the south and west of Linton.

I have traced the crops or outward extremity of these coals, and their concomitant strata, more than fifteen miles from Carlops, upon the south-east bearing, and see evidently that they do not immerge under cover, and stretch away again any where towards the south; on the contrary, they are seen to crop out in the farm of Carlops, and likewise in the lands of Magbiehill, to the south of Carlops. They are also seen to crop out upon the south side of the Wheem, which is still farther east; and afterwards they crop out over a great extent of pretty high moorish ground, betwixt the Wheem and the foot of the Moorfoot hills, to the south of Arniston.

Now, in all this extent of country, strata and rocks, of a quite different quality from the coal metals, are every where seen immediately upon the outside of the crops or outburst of the coal metals; and, as a farther proof that they do not any where stretch away towards the south-west, the river Line runs nearly parallel to them, and in much lower ground; and this river washes the superficies of the strata all the way from the Pentland hills, until it falls into the Tweed; and afterwards the Tweed runs on the surface of the strata

to Peebles; and in all that distance, which is nearly twenty miles, nothing but strata of the mountain rocks appear, which are entirely of a different quality from the coal metals; and all the rivulets and broken places of the surface, upon the south and west side of the extremity of the coals, discover the same sort of strata as are seen in the rivers Line and Tweed. Thus far I have seen the trending and outburst of the coal strata; and thus far I can answer for the truth of my observations.

To the south and south-west of Arniston, the flat coal metals approach the north-west side of the Lammer or Moorfoot hills, and there they turn first to an easterly, and then, by degrees, to a north-east direction; and they afterwards continue to crop out to the south-east, and to trend towards the north-east, until they immerge into the Forth, to the west of North Berwick. There are a few miles of this course, from the skirts of the Moorfoot hills, south of Arniston, to Blackshiels, which I have not seen; but from many circumstances, I am confident that the flat coals crop out to the south-east in that short extent, as well as all the rest of the extremity of this coal field.

From what I have advanced upon this head, I think myself fully authorised to make the two following inferences, which are naturally suggested as the result of this investigation: First, it evidently appears, that the coals and coal metals do not immerge under the high mountains, stretch

away under them, and rise again upon the other side: and, secondly, it also appears evident, that coal-fields or coal-countries are but patches of limited, though different dimensions; so that the extent every way of the coals, and their concomitant strata, wherever found, may very aptly be called the coal-field, as different fields of corn or grass are of different dimensions, but still they all have their limits.

The Midlothian coal-field is nearly a square of about fifteen miles. The Frith of Forth is the boundary of the north end of this square. The west side of it trends away from the shore of the Forth near Duddingston, towards the south-west, in a line almost parallel to the Pentland hills; but this line, by slow degrees, approaches nearer to the south-east side of those hills as it advances westward, until at last it comes in contact with the base of the hill at the bridge of Carlops; and this line, from the sea-shore to the bridge of Carlops, is about sixteen miles long, and there that line and that side of the coal-field ends.

From Carlops, the coals and the coal metals trend away in a south-east direction to the skirts of the Moorfoot hills, pretty nearly in a straight line; and I suppose that the distance betwixt Carlops and the Moorfoot hills, in that line, is about fifteen or sixteen miles.

From the point where the coal metals approach those hills, they trend away in a north-east direc-

tion, parallel to the line from Duddingston to Carlops; and this north-east line continues until the coals and coal metals immerge into the Forth, a few miles west of North Berwick. This south-east side of the coal-field is probably somewhat longer than the north-west side, which runs parallel to it.

The public road to England from Edinburgh, by Dalkeith and Blackshiels, runs almost in a right angle across this coal-field. I think it is fifteen miles from Edinburgh to Blackshiels. The coal-field commences upon that road about two miles south of Edinburgh, and it ends near Blackshiels. Coals have been wrought near that place upon the north side, and I have evidently seen the mountain rocks a little way south of Blackshiels; and, therefore, the southern extremity is thereabouts, so that the line across the coal-field upon this road is about thirteen miles long. The line across it, upon the road from Leith to Haddington, is likewise about thirteen miles, and a line drawn across this coal-field farther west, would come to be much about the same length, which shows, that this coal-field is about sixteen or eighteen miles long upon the line of bearing, and about twelve or thirteen miles broad, in a line at right angles across the bearing of the strata; but it should be remarked, that we cannot determine exactly the length of this coal-field upon the line of bearing, because its north-east extremity of the

coals immerges into the south side of the Frith of Forth.

From Easter Duddingston to Carlops, the crop, or outburst of the coals, trends towards the south-west; but from Carlops to the foot of the Moorfoot hills, the outburst, or crop of the coal, trends towards the south-east, at right angles to the former course. However, in this south-east line, from Carlops to the Moorfoot hills, other strata, of quite different quality from the coal metals, emerge from under the outburst, or crop of the coals and coal metals, and trend away towards the south-west, in the exact line of bearing which the coals lost at Carlops, which is the true line to which the strata trend in general through this island; and it is to be observed, that the strata of the mountain rocks, and their line of bearing, are found immediately in full perfection of quality and regularity of strata when they first appear from beneath, and immediately to the westward of the coal metals. From which circumstance, in conjunction with many others, it evidently appears to me, that the coals and coal metals were among the last formed of the strata which compose the surface of our globe, at least in this part of the world; but I will not enter upon such abstruse disquisitions, as it is my intention to keep as close as I can to the instructive parts of the natural history of the coals and the coal metals.

I imagine that I have already been abundantly

particular and explicit in proving that the coals and coal metals do not push their way beneath the mountains, and emerge again upon the other side; and in proving that coal-fields are but limited patches, the extent and boundaries of which may generally be traced out and ascertained, an instance of this I have given in the coal-field of Midlothian.

What I have hitherto produced upon this head, may be considered as direct and positive proof. But I shall now beg leave farther to point out a few other circumstances which immediately relate to the subject, and may be considered in the light of collateral proofs of the double point under consideration.

With respect to the coals diving through beneath the mountains, and emerging again upon the other side, it is perhaps very rare, if ever, we find them, upon the other side of a mountain, composed altogether of the same strata of coal metals, in the true line of bearing; and if such a thing should happen, there is yet, besides all that has been said upon this head, another substantial objection to their being the same coals and coal metals. I never yet saw, and I am persuaded that no other person has yet seen, the same class of coals and coal metals in any two fields, so distant from one another as upon the opposite sides of great ranges of mountains. Such classes of coal seams, and their concomitant strata, would be perfectly

well known again by men of skill and experience, by their number, quality, thickness, relative position, and other characters; but the truth is, we never see the very same coals, &c. in any two very distant coal-fields, much less upon the opposite sides of ranges of mountains.

But, in order to throw all the light I can upon this subject, and to place it in as clear a point of view as possible, it may be proper for me to point out the difference between a real range of mountains, properly so called, through or under which the coals do not pass, and such lesser hills as are frequently found dispersed here and there, within the limits of the coal-field or coal-country.

A range of mountains, properly so called, is generally composed altogether of various mountain rocks, that is, of such different rocks and strata as seldom or never accompany coal, and among which no seams of coal are ever found; these mountains are generally of greater dimensions, in height, breadth, and length, than such lesser hills as are sometimes dispersed through the coal country. What I call the lesser hills, which are often found dropt here and there within the limits of a coal-field or coal-country, are generally composed of such rocks and strata as very frequently accompany coal; and sometimes the coal seams stretch away in the line of bearing, quite through these hills.

Philosophers and naturalists, who are not profi-

cients in this science, may be led to imagine, from the rugged craggy appearance of some of these lesser hills, that they are composed of materials altogether foreign to coal; and as coal is frequently found upon both sides of such hills, they may perhaps be led to conclude, that the coals and their concomitants dive down and shoot away under the hills, and emerge again upon the other side. But this is one of those hasty conclusions, where too much is taken for granted, and before all circumstances have been fully investigated. If all circumstances were examined, it would be found, that although these hills should in some places exhibit externally a rugged and formidable appearance, they are nevertheless composed of such rocks and strata as frequently accompany coal. Such, for instance, are many thick beds or strata of basaltes, commonly called *whin rocks*, which are frequently found in the coal-fields of the Lothians, Fife, and other parts of Scotland. Now, these strong beds of rock are not only found in the coal countries, or in the neighbourhood of coal-fields; they are also frequently found both above and below seams of coal; and coal-pits are frequently obliged to be sunk through them, as at Borrowstounness, Bathgate, &c.

It is remarkable of the basaltes, as well as of some other very hard and strong rocks, that although they are found disposed in beds or strata, with other regular strata above and below them,

yet the basaltes are often found very thick and very irregular in the thickness of each stratum. In one place, a stratum of this rock shall not be above two or three fathoms thick, and farther forward upon the line of bearing it shall be found two or three times, nay in some places six times as thick. The basaltes frequently swell greatly in thickness, and rise up from a plain to a considerable mountain, as the beds of it advance in the true line of bearing. The same phenomenon frequently happens to strong beds of the mountain limestone. I have in many places seen the lime rock swell out, and increase from two or three fathoms to more than a hundred fathoms thick.

An instance of coal seams, and their concomitants, stretching through some rocky rugged hills, may be seen in the Bathgate hills, in West Lothian. These hills in some places are remarkably craggy and rugged, and of considerable height and extent; nevertheless, they are entirely composed of coal metals, and several seams of coal stretch quite through their whole breadth, from side to side; and some of these seams have not only been wrought upon both sides, but they have also been wrought up the sides, and in several places upon the summit of those hills. There are in the structure of these hills, besides the seams of coal, strata of freestone, blaes, and other constant attendants of coal, several beds of limestone, of the coal metal species; and there

are also several strong beds of basaltes, which in some places rise up to a considerable height, producing a rough and formidable appearance; and I know that seams of coal rise up among the highest crags of these hills.

In the instance of the Bathgate hills, and of many others that might be produced, we evidently see that the coals do not dive away under the mountains, and emerge again upon the other side. If they pass through mountains at all, they stretch up to the summits of them, along with their concomitant strata,—are a proportion of the constituent parts of the composition or structure of such mountains; and the superficies or crops of the coal seams rise up to the day, wherever they stretch into or through such mountains.

With respect to the supposition of the coal seams stretching away in the line of bearing, I know not where or how far, it may be remarked, that there are but very few coals as yet discovered in Ireland, although the numerous seams found in Cumberland, and those of Airshire, point towards that island, as well as those of Lancashire and North Wales; and many of them are known to immerge into the ocean upon the British side, but they are not found to emerge again upon the Irish side of the water. If these British seams of coal continued in the line of bearing, as many confidently assert, they should emerge from the ocean upon the other side, and appear again upon the Irish

shores, there being neither mountains nor hills by the way, in the line of bearing, to conceal them from discovery. I have not heard of any coals being found in the Isle of Man, which is much nearer than Ireland. But I need not insist upon this topic. The matter of fact is abundantly evident; and whoever examines circumstances in all parts of the countries he is best acquainted with, will see instances in proof of what I have advanced upon the subject.

FROM the tenor of the above dissertation upon the disposition, stretch, and bearing of the strata of coal through a country, there is one very important lesson that may be treasured up by every person concerned, who is at pains to examine the subject; namely, that it is not prudent, that it is often dangerous, to lay out large sums of money in trials for coal at any considerable distance from the place where the coal is seen and known, upon the faith of the strata continuing the same stretch and line of bearing invariably; and that before we begin upon an expensive plan, we should procure a perfect history of the concomitant strata which are found above and below the coal; and if we fail to discover and to recognise them with sufficient certainty, we have good reason to suspect that the coal is thrown off its ordinary stretch and level, or out of its ordinary course, or line of bearing, by some of the many accidents which I have de-

scribed above. If the particular strata which accompany the coal in the field where it is seen and wrought, are not found in the same order and relative position as in the former field, it is quite out of nature to expect to find the same coal without them; and even though strata are discovered, which appear like them, it will not do, unless they be really the very same. There is often a very near resemblance in the appearance and characters of particular strata in quite different fields, and sometimes in different places of the same field; yet there is always such difference, either in the particular stratum itself, or in some of those immediately above or below it, as will be readily distinguished by a skilful eye.

This lesson may be of singular use to such gentlemen as are persuaded that there is abundance of coal in their estates, because their lands are situated in the line of bearing towards which the coals trend, which are now working at some distance, perhaps two or three miles off. The want of sufficient knowledge in these cases, frequently occasions many blunders, much needless expence, and subsequent vexation, when their sanguine, but ill-grounded hopes are frustrated. They should either see the coal itself, or several of the known concomitant strata, before they make themselves sure of a coal which is wrought in their neighbourhood at a considerable distance, and where no coal is near to justify a presumption of its being in

the place desired; they should either see the outburst or crop of some coal, or at least they should see several of the known concomitants of a particular distant coal, which points that way, before they proceed to expensive trials, or indeed to any trials at all.

Several coal-masters and other gentlemen who have paid some attention to this branch of natural history, are of opinion, not only that the coals stretch away under the mountains, and emerge again upon the other side, but also, that the seams of coal dive down to the centre of the earth. They see that all seams of coal have certain degrees of declivity, excepting only that in some places the coals and their concomitant strata acquire a temporary flatness, or wave up and down with different dips for a short space; but they know very well at the same time, that these variations in the position of the strata are not permanent, and that in general they all decline less or more towards one particular point; and, therefore, from this true observation, they conclude that all coals dip down to the centre of the earth. But although I acknowledge the justice of the observation, that the strata in general decline less or more in all coal-fields towards some particular point, yet I cannot join with them in the inference. I am rather of the contrary opinion. I imagine that the coals and coal metals do not dive down to any very great depth; and I find myself obliged in this place to

lay more stress upon my own opinion than in any other part of this history, as I find it difficult to clear up the point to the conviction of every inquirer, by adducing obvious and satisfactory examples.

However, I shall offer a few observations in support of my opinion, after premising, that with respect to the centre of the earth, or the semi-diameter of the globe, two or three hundred fathoms, or two or three thousand fathoms, are neither of them a great depth. It is but very rare that we sink two hundred fathoms perpendicular under the surface of the earth, which, comparatively speaking, is but a superficial scratch, and, therefore, we are not enabled to form any judgment of this matter from the observations to be made below ground; but as the question is merely curious, I shall not be very anxious to defend my opinion by the observations which I have made above ground.

When treating of the bearing and declivity of the strata of coal, it was observed that some coal seams are known by real experience to crop out every way. Instances in point may be adduced. The seams of coal and their concomitant strata, in the north-west side of the Midlothian coal-field, dip towards the south and south-east; and the coals in the south and south-east side of the same field dip to the opposite side of the compass, viz. towards the north and north-west. This fact is commonly known upon the north side of this

coal-field, and it is obvious upon the south side of it, in the parish of Temple, and other places farther east.

Now, this does not look like the coals dipping down to the centre of the earth. It rather looks like their declining a little way down from the surface of the earth to a sufficient depth to be preserved fresh and good, until the exigencies of society have occasion for them; and when they have declined down so far, they then become quite flat, and afterwards rise again upon the opposite side of the coal-field, with an opposite dip and rise, and so form a great trough, resembling a valley, which is one of the best similitudes of the position of the seams of coal in a coal-field that can be imagined.

Let us suppose that the middle or lowest part of the valley resembles the deepest part of the trough of the coal. There are in some extensive valleys several inequalities of surface, which resemble the waving of the strata of coal up and down, when they turn flat or horizontal. However, when we have quite crossed the valley, we always come to a sensible and a decided rise or ascent of the ground, which brings us out of the valley; and, from my own knowledge and observation, I am clearly convinced that this in general is the true description of the disposition of the strata in every coal-field, though perhaps it may not every where be an easy task to investigate all the phenomena.

Many examples of this might be produced, besides the Midlothian coal-field; I shall, however, mention only one. The range of coals and coal metals which are found upon the north side of Dunfermline, and trend from thence by Halbeath, Sir John Henderon's colliery, and farther east in Fife, decline at Halbeath, &c. towards the north or north-west. The Fife coal-field, in which there is a great number of seams, reaches in length from Stirling to St Andrews, and I suppose that it is in some places about ten miles in breadth. Now, all the seams in the south side of this extensive field, dip with various degrees of slope towards the north or north-west; and, as has been observed of the Midlothian coal-field, they wave up and down over a great extent of country, and at last they rise again and crop out upon the north side. In the rivulet above the village of Dollar, and immediately below the magnificent ruins of Castle Campbell, coal metals may be seen in the bed of the mill-lead, cropping out to the day, and dipping precipitately towards the south, and the strata of the mountain rock commencing and appearing immediately below the freestone and other coal metals; and the very place where the different ranges of the coal metals and the mountain rocks come in contact, may be traced. Immediately above where the coal metals finally crop out, the rivulet emerges from a deep, rocky, and impassa-

ble gulph below the old castle, which place is every way a curious romantic scene.

The result of this investigation refutes by inference another erroneous opinion concerning coal, which I have often heard asserted with great confidence, viz. that coal is inexhaustible. That the fund of coal treasured up in the superficies of the globe, for the accommodation of society, is very great, I readily acknowledge; but that it is inexhaustible, in the proper sense of the word, I deny.

Some portions of particular seams of coal may be situated so deep below the surface, that it may be impracticable for man to work out all the coal in such places, and of consequence all the coal in such particular spots will never be exhausted; but this circumstance does not imply that coals in general are inexhaustible. I know well, and when I come to explain the real origin of coal, I will make it appear, that the source of coal, or the matter of which it was formed, though copious, was limited in quantity; and, therefore, the quantity of coal is also limited. Indeed, the real origin of coal may justly be produced as a sufficient reason why so many extensive regions of the world are absolutely without any coal at all. But I shall afterwards resume the consideration of this subject.

CHAP. X.

OF THE INDICATIONS OF COAL, AND METHODS OF SEARCHING FOR IT.

It appears to me a matter of importance, that the indications and external appearances of coal should be known, especially by those who have landed property in coal countries. Many such, I have no doubt, will be glad to have the true and infallible symptoms of coal pointed out to them, and distinguished from those that are false and doubtful.

Some whose estates lie contiguous to certain coal-fields, will no doubt have coal in their own grounds, and others will be confident they have coals, whether it really be so or not; for it frequently happens that those who are wrong, or ought to doubt, are nevertheless the most confident. I will, therefore, for the instruction of all concerned, make some inquiries about the appearances of coal, and I will carefully endeavour to distinguish the true and infallible from the false and doubtful indications. It may be said with truth, that coal itself, in some form or other, is the most infallible appearance of coal; but this is too general.

In order to enter properly upon this branch of inquiry, let us go back and look to the various sections of the strata of coal, and their concomitant strata, which I have already pointed out in the rivers and rivulets of Midlothian, &c. and likewise to the various sorts of strata which I have shown to be the immediate roof and pavement of coal. We should also go back and examine the history of the disposition, bearing, and declivity of the strata of coal, and their concomitants, where it evidently appears that the seams of coal, and such strata as accompany them, all crop out to the solid superficies of the globe somewhere or other.

This foundation being laid, we can proceed upon pretty sure principles in our search for coal. It being once understood that the one side at least, if not both sides of every seam of coal, rises up to the surface of the globe, and crops out somewhere, it is our business to go to such places where the superficies of the strata have a chance of being discovered; as, for instance, to the rivers, rivulets, gullies, rocks, and ditches, in some of which may be had a view of the prevailing strata of the country; and if they be of the class of coal metals, we are so far encouraged to proceed.

But I will beg leave to repeat here an observation which I made before, viz. that there may be, and certainly are, several species of the coal metals, or of such as exactly resemble those that ac-

company coal, in several places where no seams of coal are to be found. Such, for instance, are several varieties of the white and of the red freestones, &c.; but, on the contrary, the black and bluish blaes and soft coal tills, in which there are frequently found balls of ironstone, and the grey bands, or greyish thin strata, of a flaggy stone, in the composition of which, and often between the beds, there is found a small quantity of the substance of coal; these are seldom or never seen but in a coal-field or in a coal-country.

In working freestone quarries in a coal-country, there is often seen blackish beds of a coal-like substance between the strata or beds of stone, and there frequently appear small quantities of real coal in the heart of the stone when broken. These symptoms are not found between the beds, or upon breaking the freestone, in countries where there is no coal; and, therefore, where these symptoms are found, they are so many signs of the coal neighbourhood. But it is impossible from these alone to know how near or far off you are from a stratum of coal; and, therefore, it is necessary for us to proceed a little farther in our search.

I have laid it down as an established fact, that the seams or strata of coal rise up to the superficies of the globe as well as all other strata; only they do not always push up so boldly to the very surface of the ground, as many hard stones and other

indurated strata are found to do; for, on account of the tender and more friable texture of the coal, the superficies of the stratum is often mouldered down, and lies concealed under a thicker or thinner bed or cover of clay, gravel, sand, or earth. However, the superficies of the seam of coal is frequently discovered where the concealing substances which covered it, are washed off the face of the strata by rivulets, or are cut through by ditches, &c. so that the stratum of coal is sometimes laid bare, and may be distinctly seen: but more frequently some obscure and imperfect appearances of the outburst or crop of the coal, such as small bits or grains mixed with the soil, can be discovered. In searching a ravine, rivulet, or gully, and discovering grains or small bits of coal in any part of the slope, such grains point out the seam of coal to be higher up than the place where you stand. If you discover a quantity of soft, black, soot-like matter, you should dig in it, because it is very probable that you have found the crop of a seam of coal, as the superficies of some coal seams are dissolved into a soft mass, resembling black friable earth, in which sometimes there is not a grain of coal to be seen immediately at the surface; nevertheless, if you dig down a little in it, you will soon discover grains and bits of coal. When the surface-cover of clay, sand, or earth, is so thin that the superficies of the strata are touched in cutting ditches, and by the plough, the out-

cropping of a seam of coal is in that case frequently discovered by grains of coal of different sizes, or a quantity of black sooty stuff being thrown up. Perhaps at first this black matter will not look like coal; but if you examine it narrowly, and especially if you dig in it, you will soon find small bits of coal, though perhaps at first no bigger than peas. In digging down for trial upon a real or supposed outburst or crop of a seam of coal, it is necessary to have some knowledge of the declivity of the strata in that ground, both with respect to the point of the compass towards which they slope, and also of the degree of declivity, in order to know how to push the cut you are digging towards the dip, otherwise you may soon cut through and overshoot the appearance of coal, and find nothing below but clay or rock, or some other earthy or stony matter.

It is very well known, that the crop or outburst of some coals spread upon the surface, sometimes to a considerable distance from the real and solid crop of the coal where the seam is to be found betwixt roof and pavement, even upon level ground; and where there is less or more declivity, it then spreads still farther from the solid stratum.

I have frequently seen the vestigia or appearance of a thick seam of coal spread upon the surface, beneath the upper soil, twenty or thirty yards from the real seam, where the surface of the

ground had a considerable declivity. The side of this vestige or appearance of coal next the solid seam, is sometimes as thick as the seam itself; but it gradually wears thinner and thinner as it recedes or spreads away farther from the seam; and it also grows worse and worse, or the more unlike coal, the farther from the seam. The side of this vestige next the solid stratum, chiefly consists of the debris or rubbish of coal broken small. A little farther from the seam, it consists of very small grains of coal mixed with a black soot-like matter; and still farther, nothing appears but sooty matter, resembling black friable earth or clay, especially if there is any clay either in the soil or under it; and at the extremity of the vestige, I have seen it dwindled away to an inch or less, of a blackish soft substance, like a thin stratum of clay. Where the surface of the ground has the least declivity, the vestige or appearance of coal is sure to spread downwards from the seam, be the slope of the strata which way it will; and the greater the declivity of the surface, the farther down we may expect to find the extremity of the vestige.

When a coal crops out upon level ground, we shall not find the vestige of it spread out so far from the seam as upon a declivity; and in this, it will not be found so thin at the extremity upon a plane as upon a declivity. When a stratum of coal crops out upon a plane or level field, there is one remark to be made concerning the vestige

of it, which is different from the declivity. Upon a plane, the vestige of the coal always spreads out in a line right forward from the acclivity or rise of the seam of coal.

But I must be more explicit. Let us suppose, then, that the stratum of coal declines or dips with an easy slope towards the south-east: in that case, the rise or acclivity of the seam is towards the north-west, so that the vestige of the coal will be found a little way from the solid seam farther towards the north west: and, therefore, when a vestige of coal so inclining is found upon level ground, and you have cut through it, and found different soils below, you must then turn your face towards the south-east, and dig away in the vestige, keeping your cut down to the clay or rock, or whatever matter you find immediately below the vestige of the coal; and by following the appearance of coal towards the real dip of the seam, it will not be long before you will find it solid between roof and pavement.

This circumstance of the vestige or crop of the coal spreading forward in a line with the acclivity of the seam, makes the knowledge of the declivity of the strata in that place very necessary, as without it you do not know which way to push or advance forward with your trial for the coal, although you should find a flattering appearance of it. But in discovering some appearance of coal upon an inclining plane field, or in the side of a

glen or dingle, or any other description of sloping ground, the case is quite different. To whatever point of the compass the dip and rise of the strata should happen to be, the vestige of the coal is sure to slide down the slope of the ground, and we are sure to find it spread thin in proportion to the precipitance of the slope, and the distance from the solid crop of the seam of coal.

In searching for coal, it is necessary, in the first place, to be well acquainted with the appearances and characters of the various concomitant strata: and, secondly, to be acquainted with the various symptoms and indications of a seam of coal, which I have now under consideration. Having acquired these two branches of knowledge, the next thing to be done is, to examine carefully all the ravines, gullies, rivulets, scars, and ditches in the grounds, with such rocks and precipices and other places where the superficies of the strata may be seen. It is in these scenes that we discover what the solid superficies of our globe is composed of; and the variety which we behold, and the discoveries which we make, are a never-failing source of pleasure and entertainment to an inquisitive and intelligent mind; and it is in these broken scenes of nature that we have the greatest chance of making mineral discoveries of various kinds, and particularly discoveries of coals and quarries.

Sometimes the crop and bearing of strata of coal run parallel to one of these ravines or gullies for

a considerable length of ground, and sometimes they cross the glen or dingle in a right or a diagonal direction. When a stratum of coal crosses a glen in any angle whatever, there is a probability of discovering the crop of the seam, or some indications of it, either in the bed of the rivulet or upon one side of it.

It is not uncommon, in some places in coal countries, to find the superficies of the strata washed clean by a river or rivulet; that is, to find the seam or stratum of coal in its proper regular position in the solid superficies of the strata, at full thickness and in perfect form betwixt roof and pavement, dipping towards the same point with the ordinary declivity of the strata in that place: But it is more common to discover in such places only some appearances of coal, which frequently require knowledge and acuteness to discern, with skill and judgment to make a proper use of the discovery.

I have all along, in this history, inculcated the necessity of some proficiency in the natural history of the various strata which compose the structure of the superficies of our globe, in order to qualify us for researches of this kind. In the present case, it is necessary to have some knowledge of the bearing and declivity of the strata, in the place where any indications of coal are found, before we can form any judgment of the discovery, and know how to make a proper use of it.

When a seam of coal runs parallel to a glen or gully, and crops out any where within the banks upon one side or the other, there is a great chance of discovering some indications of the coal, perhaps in several places as you advance up or down the glen.

I have shown already, that the outburst, or superficial vestigia of a stratum of coal, upon a slope, is always found to slide downwards, and that the longer and more precipitate the slope is, the farther down the vestige will slide when the crop of the seam happens to be high up. I have also shown, that the extremity of the vestige of a coal seam at the surface is sometimes converted into a soft sooty substance, hardly distinguishable from a thin stratum of black clay or earth; but this is not always the case. The debris of some of the splent and cannel coals frequently remain in hard and sharp masses of various sizes, even when mixed with the soil, and removed at some distance from the solid crop of the seam; and some of the cherry coals, or *roch coals*, as they are called in Scotland, do not dissolve upon the surface into an undistinguishable mass, like a friable clay; but, on the contrary, although the debris, or coal rubbish, at the surface, should be broken very small, yet there will be found some sharp angular grains and bits of coal, of the size of peas, nuts, and plumbs. In places where seams of coal crop out, some appearance of the coal will be seen, by an observing

skilful eye, in such glens as we have been speaking of; and sometimes masses of splent or parrot (*i. e.* cannel coal), of a larger size, are found upon the side, or at the bottom of a ravine, which have slipt down by degrees from the crop of a seam of coal situated above.

From these inquiries it appears, that the vestigia and appearances of the outburst or crops of different seams of coal, are of three sorts: 1*st*, Pretty large masses of hard coal, not so apt to dissolve when exposed to the influence of the external air: 2*d*, Smaller masses and grains of cherry coal, of a diced or cubic form, which is frequently mixed with a soot-like coal dust: And, 3*d*, Coal dust, without any visible grains and masses, sometimes resembling soot, and sometimes hardly distinguishable from a blackish or dark brown friable earth. These particles of coal are frequently found mixed with the upper soil upon the side or at the bottom of a glen or gully; and sometimes they appear under the upper soil, upon the face of the rock, in some break or scar.

When these appearances are discovered within the banks of a ravine or glen, the first thing to be done is, to go to a place where the superficies of the strata are to be seen in the same glen, and to examine the points of the compass towards which the strata trend, and incline or dip; and when these points are ascertained, you will be enabled to know whether the strata run parallel to, or cross

the glen where the appearance is found. If the bearing of the strata is either parallel, or nearly parallel, to the trending of the sides of the glen, you can easily discover the seam of coal by digging small pits, at a proper distance from one another, cutting through the vestigia of coal, and in a line up the slope; and if the last of these, that is, the uppermost, should happen to have no vestige of coal, it is very probable that you have overshot the seam, and in that case you must go back to the next pitting in which the appearance of coal was found, and dig a cross cut in a line upwards, and you cannot fail to cut the surface or crop of the seam of coal, if you dig to the face of the rock or solid strata. If the bearing of the strata crosses the glen, either at right angles or in a diagonal direction, your digging then must be directed across the course and bearing of the strata; and perhaps in this case it may be more proper to dig a trench, in a line from the place where the vestige of coal is found, than to make pits; the trench to run across the bearing of the strata: But of this those who are upon the spot must judge which method of trial is best, as circumstances vary considerably in different places.

But it frequently happens that the superficies of the strata are not to be seen in several places; in many glens the face of the solids being often concealed under a deep or thick cover of gravel, sand, or clay.

It is very common in a coal country to find banks or beds of small gravel, and likewise beds of sand and clay, mixed with small masses of coal of various sizes, which indeed is an indication of being in a coal country; but such bits of coal so found are no indication of a seam of coal in this place: nevertheless, a seam, or seams, of coal may be there, but the bits of coal lodged in the banks of sand or clay are not the vestigia of them, as these masses of coal have been carried there when the rest of the sand or clay with which they are blended was deposited; and, therefore, it is necessary, when you find small masses and grains of coal, to be able to judge whether they are mixed with the natural soil, or in adventitious beds or banks of gravel, sand, or clay. If amongst adventitious matter, you need not dig, unless you have some other more certain indications of a seam of coal being near.

Of all the beds and banks of adventitious matter which are found above, and conceal the superficies of solid strata from view, clay is the most common in coal countries. Though it frequently happens that we have to dig through sand or gravel in sinking coal-pits, yet we more frequently sink through clay; and of all the species of clay, a strong, hard, and dry clay, mixed with less or more of sand, gravel, or stones, is the most common in coal-fields. When this species of clay is blended with boulders and bullets, with some gra-

vel and sand, it is frequently very strong and dry, and almost as hard as a rock. In some places this species of compounded cover-clay contains specimens of all the strata found in the neighbourhood; and when it is of this sort, which may be called a general composition, it is frequently a very curious and a very confused mass of indigested matter. Grains, masses, and fragments of every species, quality, and colour of the strata to be found in that country, are promiscuously blended in this heterogeneous species of clay.

There are in some places vast beds and banks of these compounded clays, which cover and effectually conceal the superficies of the strata for a considerable extent; sometimes over the whole face of an extensive neighbourhood, excepting where it happens to be cut through by a strong current of water; but it is sometimes so hard that the strongest currents are not able to wear it through. I have in many places seen this species of clay from a yard up to thirty or forty yards deep, and more, above the rock or superficies of the strata; and, as I hinted above, it frequently contains specimens of the coal, and of all other strata found in the neighbourhood. I have often seen such a quantity of larger and smaller masses of coal blended in this sort of clay in some particular places, as might deceive many, and make them imagine that it was the vestige of the crop of a seam of coal. I know that many do imagine

it, and I have no doubt that several will be induced, from the quantity and variety of bits of coal found in different places in this clay, to make some trial in it; and for such as are not very well acquainted with this composition, perhaps it would be wrong to dissuade them altogether from digging a little in it, because it is in some instances pretty difficult to distinguish between the vestige of the crop of a seam of coal, and a nest of bits and grains of coal blended in the compound clay; especially when we consider and know that a real outburst of the crop of a coal is frequently mixed with clay at the surface of the ground; and, therefore, when appearances are so doubtful that it cannot be distinguished with certainty whether the masses and grains of coal which are found, be the vestige of a seam or adventitious, it may be proper to dig a little. If the appearance of coal, upon which the trial is made, be adventitious, and belonging to the compound clays, the symptoms will not alter much upon digging in it, there being sometimes a great depth of this clay above the superficies of the solid strata, so that there will be no material change in digging. No appearance of a stratum of coal will be found; nothing but the same compounded clay continuing with adventitious grains and masses of coal in it, which coal is part of the composition; and the whole mass of the clay, as well as the coal, is adventitious.

I hinted before, that it is the character of some beds of this clay to be compounded of specimens of all the neighbouring strata; and in fact, these specimens, and the whole of this composition, have been torn off the superficies of the strata by water, soon after they were formed, before induration was complete; and the matter so torn off was carried forward a little by the weight and force of the high tides; and when the tides began to abate and fall lower and weaker, these beds of clay were left as we find them, when the weight and force of the water failed.

The numerous hillocks and extensive beds of gravel which we see in so many places upon the face of the earth, have the same origin. Those gravel beds and banks are also a composition of various species of such strata as were indurated and they were likewise torn off the rocks; and after being rolled in the waters until all the asperities and sharp angles were worn off, the whole was lodged as we find it.

As several of these beds of compound clay contain specimens of all the strata of the neigbourhood, which may be easily proved by comparing the specimens with the strata from which they were broken off, and as coal is a part of this composition, I give this as another symptom or indication of coal, which may be called an infallible one. I cannot, it is true, by seeing this symptom of coal, pretend to say there is a seam of coal with

in so many yards, or within so many hundred yards: I have, nevertheless, no difficulty to assert that there is coal in the neighbourhood where this compounded clay appears with masses and grains of coal in the composition.

I have been thus explicit in pointing out the difference between small masses of coal discovered in the compound clay, and the real vestige of the crop of a seam of coal, for the information of such as cannot yet perfectly distinguish the one from the other.

After this explanation of the origin, appearance, and component parts of these beds of cover-clay which so frequently conceal the superficies of the strata from our view, I hope that all who are interested, and even such as are not adepts in this science, will be able to distinguish between small masses or bits of coal found in beds of clay, and such as belong to the real outburst or crop of a seam of coal; and in cases where they are not certain at first, and resolve to dig, they will soon be able to distinguish between the vestige of the crop of a seam, which is generally continued, and increases from the first discovery, until we find the crop of the seam betwixt roof and pavement; whereas the bits found blended in the compound clay are generally detached from one another, are imbedded in a vast mass of clay, without any continued stratum or vestige which might lead to a seam of coal; and, therefore, when digging pro-

ceeds in a bed of this species of clay, it will be needless to proceed, there being no hopes of making any discovery in it.

There is one circumstance yet to be remarked: The masses and bits found in the compound clay are generally hard, clear, and perfect; whereas the bits found in the vestige of the crop of a seam of coal have frequently a decayed imperfect appearance, sometimes quite decomposed or dissolved into dust, resembling soot or black earth; and where there are small masses of coal, they are generally tender and friable, and blended with coal dust, excepting in the case of the seam of coal containing a stratum of hard parrot or splent, as these sometimes produce pretty large masses, which have fallen down the slope, or scattered about the surface, at a considerable distance from the crop of the seam of coal. These larger masses frequently appear in considerable degrees of perfection, without any other vestige of coal, at a distance from the seam, though other vestiges may be found nearer to it. Masses of cannel and hard splent coal bear tumbling about, and they bear the external influence and changes of the air without injury as well as some stones; but all the cherry coals, roch coals, and some of the splents, decompose at the surface, and fall either to dust or to small grains; and it frequently happens that some parts of the same stratum of coal dissolves to powder, and other parts of it fall down into small pieces,

or to grains and bits of various sizes; and these are found blended together either upon the surface of the ground, or under the cover-clay or other matter.

I observed before, that the appearance of coal is sometimes so near the surface as to be discovered by the spade and by the plough; and I have frequently seen small bits or grains of coal mixed with the soil cast up by the mole, when the superficies of the strata happened to rise to the surface of the ground. But when bits or grains of coal are cast up by the plough or by the mole, it should be considered and judged whether such grains of coal are adventitious, or belong to the vestige and crop of a seam.

Coal has been laid down in a vast number of places upon the face of the earth for burning lime and bricks, and for many other purposes, and a quantity of the small debris of it will remain; and, moreover, where coal is burnt for common fuel, a quantity of the debris of it is carried out with the ashes and spread over the fields. In these cases, bits and grains of adventitious coal will appear after the plough, and in the mole hillocks, where no seam is to be found.

I have already recommended an examination of the glens and rivulets, and all other places where the superficies of the strata may be seen which are likely places for discovering strata of coal.

It generally happens in all coal-fields or coal-countries, that the superficies or outburst of a great number of seams of coal are to be seen in such places; but of all the places where coals are discovered, new-made ditches are the most remarkable. However, it must be noted, that no mineral discoveries of any kind can be made in ditches, by forming roads, or by any other superficial methods of digging, where a thick bed of clay, or a bed of gravel or sand, covers the superficies of the strata; but where the rock or strata come up so high as to be found immediately below the upper soil, or under a very thin bed of surface clay, the vestige of coal is frequently thrown up by ditching.

I need not observe here, that the symptoms or indications of coal appear in ditches by black strokes across the dyke or bank thrown up out of the ditch, which strokes or stripes are sometimes discernible at a considerable distance.

When ditches are cut across the crop of a seam of coal, they throw up a quantity of black matter upon the top of the dyke, which generally appears obvious; but the vestige of coal so thrown up is not always distinguishable at first sight from the vestige or crop of blaes, and all the black coal tills. The one is generally as black as the other to appearance, and, therefore, circumstances must be well examined.

If a quantity of black argillaceous matter is dug

through and thrown up, without any bits or grains of coal appearing in it upon examination, then it may be concluded that blaes or some species of black coal till have been only cut through; but if any bits or grains of coal are found, some trial should be made by digging.

I hinted before, that the extremity of the vestige of a seam of coal is sometimes no better in appearance than an inch or two of black clay or earth. When such a faint and obscure appearance is found in cutting ditches, it should be narrowly inspected, to see if any symptoms of coal can be found in it, such as small grains of coal, or if it be of a friable quality and appearance, like wet coal dust. In this doubtful case you should dig a little in it, following the vestige towards the acclivity, if the ground is sloping; but if it is a perfect plane, towards the strongest side of the vestige, and if a seam of coal crops out there, and if you are digging towards it, the vestige of the coal will increase, and grow more and more like coal as you advance towards the seam, and grains of coal will appear, which will encourage you to go on with your trial.

But the vestige of coal discovered in cutting ditches is not always so obscure. It is very common for a quantity of coal to be thrown up with the spade, which may be seen in grains and small masses upon the top of the dyke, especially after a shower of rain; and it sometimes happens

that the crop of the coal is so near the surface of the ground, that the real superficies of the seam is cut through in the ditch, and small coal with the spade is thrown up in great abundance.

When the vestige of a seam of coal is once discovered in a ditch, or in any other place or situation, it may be proper to make such trials upon it, by pitting towards the dip, or by following the vestige with a trench, as will trace the seam under cover in solid metals, or until the proprietor is satisfied. No true judgment can be formed of the thickness and quality of a stratum of coal, until it is found under the cover of solid metals, that is, until it is seen in the solid strata, between roof and pavement. When you have pursued the vestige of a coal until you have it within the solid strata, with a solid regular roof above, and a solid and regular pavement below it, you can then judge of its thickness, as it seldom alters much in thickness when you go farther down in it, and you can sometimes also judge of its quality. When you have a regular roof and pavement, you can judge of some of the characteristic qualities of the coal; you can then see whether it is clean or foul coal, that is, whether the coal is pure, and free of heterogeneous matter, or if it is mixed and blended with pyrites, stone, or argillaceous matter; or if there are beds of stone, blaes, &c. running in the middle of the seam of coal, and so dividing it into two or more strata: and sometimes

you can judge, pretty near the crop or surface, whether it will be a hard or soft coal, and if it will prove a good burning coal or not; though you cannot always judge of these last mentioned qualities so near the surface, as some coals, which appear soft, tender, and useless, when but a few fathoms below the surface, improve wonderfully in strength and quality at a greater depth, when under a great weight of superincumbent strata. Some seams of coal appear and burn pretty well when first found between roof and pavement, and others are good for nothing so near the surface, and unfit for use until they are under many fathoms of solid cover. This is very well known in experience, and generally the deeper down the better.

In my account of the external appearances and indications of coal, I have mentioned nothing about the Petroleum and Ochre which are said to issue from coal, and about which a great deal is said by many who imagine that they understand these matters; and I have purposely avoided saying any thing about them as indications of coal, for a very good reason, viz. because I would not wish to deceive. These at best are but vague and uncertain symptoms of coal; and in most places where they abound, they are no symptoms at all.

The petroleum is an oily inflammable substance, found upon the surface of the earth, which in ma-

ny places issues from the rocks, from peat bogs, and from putrified vegetables, in a thousand places where coal is not to be found; and ochre is composed of earthy ferruginous particles, carried by water from mineral bodies, and lodged or left by the water in various situations and quantities, and both of them frequently a hundred miles from coal. Why then should we attend to, or have any thing to do with symptoms so very uncertain? Some species of petroleum may have a near relation to coal; and under certain circumstances, for any thing I know to the contrary, coal may produce some of it, but I am confident that it does not produce ochre. The petroleum is not only to be found upon the surface, but also it appears to me to be an universal oil, present in lesser or greater quantity, and under some form or other in all fossil bodies, and so plentifully diffused in the atmosphere, and through all the soils, as to be one of the chief principles and component parts of all plants. It is evidently combined with, or infused in several rocks and strata, which compose the superficies of the globe. Many of the coal blaes, and of the thin slate-formed argillaceous strata of the coal metals, contain it in such quantity as to produce a strong flame when put in the fire; and some of them, when fire is applied to the side of a large parcel, will burn throughout of themselves, without the assistance of any other fuel; as, for instance, at Pitfirran in Fife, where several large

heaps have been burnt, and where the whole mass or heap grows red-hot throughout; but the fire neither consumes any of the quantity or bulk, nor does it produce any ashes; and after the fire goes out of itself, the blaes assume a pale red colour, and are so much harder than before as to make good materials for private roads. Petroleum is likewise well known to be diffused in lesser or greater quantities through the body of all lime-stone; and it is often found lodged in its cavities, sometimes of the colour and consistence of an ointment. This I have seen at the Camp and Dechmont lime-quarries, the one to the east, and the other to the west of Midcalder in Scotland.

I have frequently seen thinly stratified limestone, near a hundred miles from coal or coal metals, containing so great a quantity of this natural oil as to produce a strong flame when put in the fire, and the oil could be seen oozing out in the fire, though the stone was hard, and made a good produce of excellent lime when burnt for that purpose. I have also seen many black, shivery, and slate-formed or laminated strata of the mountain schistus, that is, such as are every way formed from, and situated at a great distance from the coal metals, produce, nevertheless, a strong flame in the fire; and I have seen, very far from coal, beds of black, hard, stony matter, breaking, or naturally separating into small angular masses, so plentifully

impregnated with this oil as to emit a strong flame when put in the fire.

Now, from all these observations and facts, and many more which might be produced, it is abundantly evident that this fossil oil is universally diffused through all substances within the superficies of our globe, and upon the surface of the earth, and is perhaps a constituent part in the composition of almost all bodies, though in widely different degrees, combinations, and forms.

I am aware that some will grant me that the petroleum, or natural oil, is found in many fossil bodies, upon the face of the earth, yet, nevertheless, that coal is the chief repository of it.

Many gentlemen are of opinion, that the flowing of the petroleum is the principal, if not the sole original cause, or the producer and nourisher of coal; and these gentlemen argue thus, and say, "That the hypothesis appears highly probable, "as it is a well known fact that different coals "are better and worse in various degrees; some "of them being very good, some indifferent good, "and others worse, very bad, and imperfect. May "we not suppose," say they, "that all these have "arrived at different degrees of maturity; that the "worst are yet far from being ripe; but that they "will all come to perfection in the course of a "very long time?"

This theory, which makes coal to be a progressive work of Nature, may appear to some plausible;

it is, however, very liable to weighty objections. We shall consider it farther in the next Chapter.

CHAP. XI.

OF THE FORMATION AND ORIGIN OF COAL.

A SEAM of coal is an original stratum, which keeps its station as regularly as any of those placed above and below it. Of this truth I have shown abundance of instances, to which I refer.

Now, if a seam of coal be an original stratum, the matter of it must have been collected, and the stratum of coal formed, when the superincumbent strata and those below it were formed. This is necessary in the nature of things, because new strata cannot now be inserted among the original strata.

This account of the matter will not agree with the supposed progressive formation, and yet this is a well known fact, obvious to the most common observation; and, moreover, the impurities of bad coals, that is, the heterogeneous matter found blended in the different seams of bad coal, are real mineral substances, such as pyrites, ironstone, freestone, and several sorts of argillaceous matter, which will keep their stations where they are;

and, of consequence, such coals as contain these heterogeneous substances, must for ever remain as imperfect as they now are; and, therefore, we must give the coal a more ancient date in the annals of natural history; and we must also allow it another origin, though the petroleum, for any thing I know, may in part be the remote origin of it.

Coal has very obvious and striking appearances of being composed of vegetable substances. I have frequently seen the grain and other characters of wood in coal; and in some inquiries and disquisitions in another place, viz. in my natural history of the strata and rocks which compose the structure of the superficies of our globe, I have shown that the antediluvian timber was the original of coal.

It will apear highly probable, from what is said in that history, that the greatest part of the antediluvian earth was covered with a tall and luxuriant growth of timber, and it is easy to conceive that so many millions of acres of tall timber, formed into coal, would produce a very great quantity of that valuable fossil: and in this respect the effect and the cause exactly correspond; the quantity and variety of coal found within the superficies of the earth, seem to agree with the immense quantity of timber which produced it. Naturalists have not only observed the appearance and characters, such as the grain of timber in coal, but they have

also seen considerable pieces of whole timber, which, though black as coal, yet not so altered as to lose the original form and grain of a round piece of timber.

From every situation and circumstance relating to the strata of coal, and of the concomitant strata, it is abundantly evident that they were all formed by the agency of water, as well as the rest of the superficies of our globe; which subject I have clearly explained in another place; and, therefore, it follows, by a natural and necessary inference, that the strata of coal, and of all the coal-field, were formed at the same time as the other superficies of the globe, though this time comprehended the continuation of days, weeks, and months; but it appears to me that the strata of coal and of the coal-field were among the last that were formed within the time alluded to; which circumstance I hinted at before.

All the beds or seams of coal are equally well stratified with the other concomitant strata of the coal-field, and the strata of coal are in every respect fully as regular as any other species of strata found above or below the coal; and besides these general characters of stratification which seams of coal have in common with the other strata of the field, a great many seams of coal exhibit, moreover, such internal marks and characters of stratification, as clearly point them out to the cursory

observer to have been formed by the motion or flowing of water.

The structure of coal, from the seams being composed throughout of a great number of thin and regular layers or strata, is often in reality laminated. Some of these laminated seams of coal are composed of a great number of thin strata of nearly the same quality and texture, and other seams contain strata or layers of two or three different species of coal. And again, some of them contain a considerable number of species and varieties of coal in the same individual seam or stratum; and these several varieties of coal of different appearance and quality, disposed in regular laminæ, and lying one above another in the same stratum. We find in one seam of coal a stratum of splent and a stratum of cherry coal; and sometimes we find strata of splent, cherry coal, roch coal, parrot, and of run splent in the same seam. There is a thick stratum of coal among the edge-seams of Gilmerton, Loanhead, &c. in Midlothian, called the Great Seam, which contains coals of several different qualities and varieties, such as splent coal, roch coal, run splent coal, a stratum of fine parrot or cannel coal, of excellent quality, and a stratum of coarse parrot of inferior quality; and there are in the same great seam varieties of the roch coals and of the run splents: so that this individual stratum contains a considerable number and variety of coal of different appearance, quali-

ty, and texture. This variety of coal is found in the great seam in all the different places where it has been worked, in a distance of several miles in length upon the bearing of the coal.

That wood is the origin of coal is so plain and evident a truth, that we can almost trace and point out the particular species of wood which composed particular species of coal; such as, for instance, we may suppose, that the long-grained resinous pines and fir timber are the principal ingredients in the composition of our fine flaming splent coal, which, like the fir timber, will readily cleave from end to end, and will kindle almost as easily, and burn as freely as the resinous fir timber itself. The like comparative characters and similitude might be found and pointed out between other kinds of wood and the other species of coal, which would be found to correspond with remarkable exactness, after allowing for the several mixtures of several sorts of wood in one stratum of coal, and for the great alteration the wood must suffer by being so long agitated in the waters of the deluge, and the great effects which composition and mineralization must necessarily have upon the appearance and properties of the several species of coal.

Some of our coals, indeed, are remarkably clean and pure for such bulky fossils placed among numerous strata of heterogeneous substances. These discover very little of foreign matter in the com-

position of the stratum; but, on the other hand, many of them are blended and mineralized with various proportions of stone, clay, pyrites, and other heterogeneous matter, which debases and spoils the coals to such a degree, that many seams are of an inferior quality, and some of them are rendered entirely useless. But as this inquiry and investigation must be conjectural, and merely a matter of curiosity, and as it affords no useful information, I will proceed no farther in it.

Coal tar, which has of late been extracted in great quantity from this valuable fossil, is another proof that wood is the origin of coal. The coal tar is so nearly of the same nature and quality as the foreign vegetable tar, that there seems to be no other difference between them than what must necessarily be communicated or acquired by the compounded mineralized state of the fossil coal: But I could wish that this proof of the vegetable origin of coal had never been produced. The discovery of coal tar will be of infinite detriment to the nation in the course of time.

The avidity for present profit will prompt many to consume the coal in making tar, which our cities, our populous countries, and our manufactories will soon want. Where iron works are carried on near the tar kilns, I would approve of making coal tar, because, in that case, the coaks produced by the kilns are used in a valuable manufacture, which is a national benefit; but where the tar and

iron works are not conjoined, at least in the neighbourhood, the coal tar is a pernicious manufacture.

But let us now return to our inquiries about the petroleum and ochre. If all our coals were found in the cavities of mineral veins, and not in regular strata, there would be some reason to suppose that coal was produced by the continual flowing of the petroleum or fossil oil; but where it really is found in regular strata, there is not the least foundation for such a supposition. It is not even possible in the nature of things. I have seen coal in the cavities of mineral veins at Castle Leod, in the highlands of Scotland. This extraordinary coal is lodged in common rake veins, or perpendicular mineral fissures in the mountain rocks, far from any strata of coal, or of the coal metals. The veins at Castle Leod open into bellies or cavities of different lengths and capacity, and close again, or check, by the sides coming together; and they have every character and description common to good rake veins. The coal is lodged in the cavities, exactly in the same manner as lead, copper, &c. are found in such veins in other places. I got some coal dug out of one of these veins, and tried it by burning: it was soft and tender, being near the surface; but it was perfectly clean and bright—about a foot thick where I opened the ground, but it grew thinner towards the ends of the belly or concavity of the vein, and it soon

dwindled away to nothing, and twitched out entirely; and I saw it open again in several places in the bearing of the vein. This coal was exceedingly fat, so as to run together strongly in the fire like the best Newcastle coal. I look upon this phenomenon in the natural history of the mineral kingdom as a great curiosity. Having never heard or imagined any such thing until this offered itself to my consideration, I was at all due pains to investigate it thoroughly, that I might not be mistaken in any point.

There are several mineral veins at Castle Leod running parallel to one another upon the north-east side of a pretty high and rocky mountain; and there are some lesser strings branching out from the principal veins.

There is coal found in three or four of these veins, part of which had been wrought out of several bellies, as far as they could go down for water, before I was there; and as I had no apparatus for drawing the water out of the old works, I was obliged to open new ground farther forward upon the bearing of one of the veins, out of which coal had been wrought. When I opened the ground, the coal was only about one foot thick, and it only continued for a few yards in length at that thickness, before it began to dwindle away by degrees, and it was soon squeezed out entirely at both ends of this little belly. I saw evidently, that some of the bellies or cavities of the veins, out of which

they had formerly dug some coal, were wider and longer than the one which I opened. Some of them were up to three or four feet wide between the sides of the veins. They had chosen the best places for their trials, which was not difficult, as the coal was to be seen in the veins at the surface of the ground. I saw coal in several places in the checks or twitches of those veins between the open bellies, not above one inch in thickness.

The circumstance of these coal veins opening into bellies, or cavities, between the sides, and twitching again by the two sides coming close together, is common to all mineral veins of this description, though the cavities of the veins at Castle Leod are remarkably short; and the twitches, or close parts, are also short, these being a species of piped rake veins; the character and description of which is, that they open and close again at short distances in the line of bearing, and the pipes or cavities put down in the dip of the vein parallel to one another.

The coal at Castle Leod will not pay for working, unless for some very particular purpose, and when other coal cannot be had but at an extravagant price. It would be a noble experiment to put down to a great depth in one of these pipes or bellies of coal, in hopes of finding some mineral ore. There is at least a probability that the coal may be cut off below, and that some of the precious or useful metals may succeed to it.

A change of the produce of mineral veins at different depths has sometimes taken place. One of the richest mines of Saxony was at first, next the surface, an iron mine. At some considerable depth the iron was cut off below by copper, and was long wrought as a copper mine. At a still greater depth the copper was cut off by cobalt; and when they had wrought some time longer and deeper down, the cobalt was last of all cut off by silver ore; and they have for a long time been working it as a rich silver mine. A change of metallic ores has been observed in other parts of Germany, besides that in Saxony. I do not pretend to infer from those instances of the German mines, that there is absolute certainty; but there is a probability that some valuable metallic ore would cut off the coal at a good depth in the Castle Leod veins.

I have seen a very small quantity of coal in some other parts of the Highlands, in small fissures of the rocks, since I saw the above; but none to be compared for quantity to that at Castle Leod; and none of it above two or three inches thick in any other place, or of any considerable continuity.

There is coal in the Isle of Mull of a pretty good thickness. I have been told that it is above three feet thick; and from the imperfect descriptions which I could obtain, I suspect it to be a vein of coal; but this I cannot positively assert,

as I never was there, nor have I ever met with a person who has seen it, and who could distinguish between a stratum of coal and a vein of coal.

I was a good deal surprized when I first saw the coal veins at Castle Leod; however, upon weighing the matter, and examining all circumstances, I was afterwards able to comprehend this phenomenon. I have in another place made it evident, that water was the agent in the formation of the strata; that all the phenomena which we behold upon, and within the superficies of our globe, were produced by water; and it was water that brought and poured the ingredients of all the mineral ores into the cavities of the veins, while those ingredients were in a fluid state, and consequently it was water that carried and poured the fluid substance of the coal into the veins at Castle Leod. I have in its proper place fully investigated and explained these subjects, where I have shewn that it was water also that spread out the fluid substance of the coal where it is found in regular strata: But I will not here enter into those disquisitions.

I think that I have now made it abundantly evident, that coal is not produced by the flux of petroleum, or by any similar operation; but that the strata of coal were formed by water at the same period of time, and in the same manner as all other strata were formed; and that the origin and source of the coal was the antediluvian timber; and, therefore, it is necessary to give up that point.

But it may be said, that I cannot possibly deny, with any shadow of truth, that coal produces ochre, as we have, it may be said, the evidence of our senses for the truth of the position; it being very common to see coals quite red and covered all over with ochre; and upon breaking the masses of coal, it is found lodged in all the interstices, so as to make it internally red as well as upon the outside; and it is pretty well known that coal lying dry, without any water about it, for a considerable time before it is wrought, is the cause of this ochry colour, and, therefore, it may appear to many that coal produces ochre, when it is found so plentifully lodged through the whole mass. But, however evident it may seem to many, I cannot grant the position, and therefore it is incumbent on me to refute it. Water is the common vehicle of all fossil particles below ground.

I have asserted above that the fossil oil is very widely diffused, and I now assert that the sources of ferruginous particles or ochre, which are known to be iron pyrites, are perhaps as widely diffused through all fossil bodies.

Iron is found in less or greater quantities almost every where upon the face of the earth and under its surface; and it is commonly very plentiful, both in balls and strata, in the neighbourhood of coal; and it is also well known that the pyrites are very near, if not altogether as common. Both are frequently found the immediate roof of coal,

and pyrites especially is sometimes found in various quantities, and commonly in flattish glebes, mixed in the stratum of coal itself.

Now, as these ferruginous substances are found imbedded in the seam of coal, and very frequently in the roof and pavement of it, no doubt corroding waters find it there, and lodge the minute particles of it in the interstices of the coal seam, where it appears in an ochreous rust when the coal has been laid dry for some time.

That water percolates the pores and fissures of the strata, and carries various particles along with it, I have explained elsewhere. While this subterraneous water is excluded from the effects of the external air, it continues to carry about the various fossil particles which are mixed in it; but when it issues into the external air, or any how approaches it, the quantity of water immediately diminishes by evaporation; and, of consequence, the fossil particles are deserted and lodged where the water left them. When a seam of coal is levelled with an adit, the water is carried off the coal by that drain. The air gets admittance into the works in great quantity through the pits and mines, and then a considerable portion of air penetrates the natural joints or cutters of the coal when it is laid dry, which evaporates the water that was in the joints or interstices of the seam when it was first drained, and the ochreous particles that were combined or mixed with the water

are left behind in such quantity as to colour the coal of a brownish yellow red.

When water containing ferruginous particles issues from an artificial adit, or at any natural vent, to the surface of the ground, part of the water is immediately taken up when it comes in contact with the external air, and carried off in steam or vapour, and then the remaining part of the water is not sufficiently abundant to carry along all the particles which it at first held in solution; and, consequently, some particles are lodged in the form of sediment, and some adhere to whatever they come in contact with, and are continually accumulated, until a considerable body of ochre is formed. The same happens in a lesser degree in the interstices of the seam of coal, and of several other fossil bodies. I have frequently seen freestone and other strata equally red with ochre as ever I saw coal, and from the very same cause, viz. the ferruginous particles, first carried, then lodged, and afterwards deserted by water.

The water which surrounds the strata, and penetrates all their pores and crannies, is plentifully impregnated with iron in a fluid form, or with ochreous particles; but when those strata are drained by an adit, or otherwise, the greatest part of the water runs off, and the remaining part is evaporated, so that the ochreous particles are left behind, and colour every body they adhere to. Take a mass of cannel or of splent coal, which is

red with ochre, and break it where there is no natural joint or crack, and the heart or solid part of the mass will be found as black as any other coal, and perfectly free from the least tinge of ochre, though the outside and all the joints and interstices should be quite red with it.

I have perhaps said too much about these vague and false symptoms of coal. My apology for so doing is this: I know that many are in danger of being deceived, and that many have been deceived by them. There is much money laid out imprudently in searching for coal upon the sole footing of one or other of these symptoms. I lately saw and examined a remarkable instance of each kind.

In one of these places a number of long mines had been driven into the sides of the hills and glens, and deep pits had been sunk in different places at great expence, upon the faith of the petroleum, because a little of it (a thin film or pellicle) was seen to issue from some beds of schistus of the mountain rock, and because some of those shivers would flame a little in the fire.

This place is situated in the mountains, at least thirty miles from coal or coal metals; but it is not at all uncommon for the schistus, or such shivery rocks, to be inflammable, from their being impregnated with fossil oil. There is not in this place the least symptom in nature of coal, or of any strata or species of rock that is found to accompany coal.

In the other instance which I hinted at, they had seen a little ochre, and therefore they certainly must have coal; for coal, said they, produces ochre: and upon this assurance of success they fell to work by sinking and boring to a considerable depth, and at great expence. I viewed this place before they gave over working, and saw nothing but grey indurated strata of the whinstone or mountain rock; nothing that had the least affinity or resemblance to any of the concomitants of coal. Upon examining the rubbish thrown out of their shaft, I found that about one third of it was iron ore mixed with a considerable quantity of iron spar. The deception is thus explained: The iron ore produced the ochre which was seen upon the surface, and the ochre led to the sinking of a shaft upon a vein of iron ore. Now these two instances are in point, and they are both eminent instances of being deceived by such vague appearances.

CHAP. XII.

OF THE DIFFERENT KINDS OF COAL.

HAVING mentioned many different sorts of coal, it may be proper to give a short description of the several known species of coal in a regular series.

There are at least six different species of pit coal, such as,

1*st*, Caking coal, of a fat bituminous or resinous quality which melts in the fire, and then runs together into one mass when thoroughly heated, and burns to a cinder with a thick fuliginous smoke; but the best varieties of it produce very little ashes.

This species of coal is commonly of a fine black clear colour, of considerable brightness when newly worked, and remarkably clean and pure, though not without exceptions, being in some places debased with clay, pyrites, and other foul admixtures.

There are several varieties of this species of coal. One of them is called cherry coal, which is of a cubical or diced structure, the most tender and brittle of all coals, which generally breaks

small in working and carriage; but the smallest coal dust of it cakes and runs together in the fire to a strong and pretty hard cinder when it is thoroughly heated, and even before it is all quite red hot. Some varieties of these fat coals exhibit no regular form or structure, but are run together in the stratum to a general confused mass, without any appearance of laminæ or other determinate figures. Some of these are soft and easily worked, and produce mostly small coals, and others of them are more hard, strong, and solid, and yield great coals in working; but none of these are quite so hard as some other species of coal.

Northumberland, and other parts of the north of England, are famous for producing abundance of this species of coal, great quantities of which are shipped at Newcastle and Sunderland, and it is commonly known by the name of Newcastle coal.

This species of coal is not quite so common in Scotland as the north of England. The greatest quantity and best quality as yet discovered in Scotland is at Balmule, near Dunfermline, in the county of Fife, where the seams or strata of coal are of good thickness; and they will, in the course of time, become of great value, when this species of coal is all worked to a great depth in the north of England. There are several seams at Balmule of excellent quality, which stretch longitudinally through a considerable extent of country, espe-

cially towards the north-east. There is also pretty good caking coal at Pitfirran, and other places in the neighbourhood of Dunfermline, as well as in some other parts of Scotland.

2*d*, The second species I shall take notice of is called *rough*, *roch*, or *rock coal*, which is a free coal of various degrees of strength and hardness, commonly of a good black colour, though not so bright and glossy as the Newcastle coal.

Most of the varieties of this species burn to a good cinder, though they do not cake, run together, or cohere in the fire; but they frequently produce more ashes than the Newcastle coal. Some of the varieties of the roch coals are as pure and as free of heterogeneous mixtures as any coal whatsoever; and these produce very little ashes; they are in fact the best of all coals for culinary uses, making a strong, clear, and open fire.

There are many varieties of the roch coals. Some of them are finely stratified, the seam of coal appearing to be composed of numbers of thin and regular strata or beds, lying one above another, strongly cemented together, and broken transversely into irregular square masses of no determinate size or figure.

Some varieties of these coals approach to a cubical or diced form, and are called *cherry coals*, although they want the caking quality. These are generally soft, brittle, and easily worked, but break

small in working and carriage. Some of the roch coals are run together into a hard strong mass, which appears of a flat or horizontal texture, but without any distinct strata or laminæ in the coal wall or seam.

In short, the form and texture of the varieties of the roch coals are so numerous, that it would be tedious to enumerate them all. Many of these coals are very hard and strong, producing large masses or great coals in working, which stand carriage well. Such of these coals as do not burn to a good cinder are debased by a considerable proportion of some earthy matter, which causes them to produce a great quantity of ashes, and this great proportion of ashes prevents or spoils the cinders.

Great abundance of this species of coal is found in the counties of Edinburgh, Linlithgow, Fife, Stirling, Lanark, and other parts of Scotland; and likewise in Shropshire and other parts of England.

3*d*, STONE coal, or splent coal, which is of a laminated or slaty structure, burning freely with a strong flame and much smoke, and producing less or more ashes in proportion to the purity or debased quality of the coal.

This species of coal is remarkably hard and strong, and difficult to break across the bed of the strata, excepting at the natural transverse cutters; but it cleaves or splits easily into thin broad flags

like boards, which kindle almost as readily and burn as freely as fir wood. No fossil bodies of considerable bulk are more regularly stratified than splent coals. Some varieties of this species are very light and pure, from which a natural oil sometimes oozes out in the fire; and these burn fiercely with much flame and smoke, but produce very little ashes. Some of these burn with such a clear strong flame as to give a light equal to that of a number of candles; and the country people in many places use no other light in the winter nights. Other varieties of it are more stony, hard, and ponderous, and produce much ashes; but some of them are so foul as to leave a white slaty mass in the fire, which will not burn down to ashes.

One variety of this coal is by Scotch colliers very properly called *run splent*. This variety is of a more clear and glossy black colour than most of this species, which is of a more dusky black than most of the other coals.

Many of the run splents exhibit a mixed texture, being partly laminated and partly uniform, like broken pitch, and some of them are laminated throughout the whole stratum; but they all appear to be of a mixed quality, and the strata or laminæ are so run and cemented together, that they will not split asunder so easily or so completely as the perfect splents

All the run splents are certainly of a mixed

quality, some of them being composed of about half and half of the second and third species, and some of them of the same proportions of the first and third; and, as a proof of this mixture, the last partakes of the caking quality of the first species in so considerable a degree as to run together in the fire, and to produce excellent cinders in burning, whereas the pure splents burn to ashes.

All the run splents are amongst the best coals in the world for culinary and all domestic uses. The splent or stone coals are very common in the Lothians, Fife, Ayrshire, and all the other coal countries of Scotland, as well as in some parts of England.

4*th*, CANNEL coal, or parrot coal, which is of a good black colour, and of a fine, smooth, solid, uniform texture, is considerably hard, and breaks in any direction. When this species of coal is clean and free from heterogeneous mixtures, it is pretty light, makes a chearful fire, with a strong flame and but little smoke; and it burns to a less or greater quantity of ashes in proportion to the good or bad quality of the coal.

Some of the best varieties of this coal are so fine and solid as to be often turned and otherwise formed into many sorts of utensils and trinkets, which bear a good polish; but they are more beautiful than durable: however, the coal is so fine and

clean as not in the least to stain the hands or the clothes when made into toys.

This species of coal is very common in the county of Edinburgh, and in many other parts of Scotland and in England.

5*th*, CULM, or blind coal, which is of a fine clear, glossy, black colour, and of a bright metallic appearance.

This is a very singular species of coal, which emits neither smoke nor flame in burning. It is not very easily kindled; but when thoroughly ignited, it burns a long time with a clear, strong heat, like charcoal, being very durable, and without the least smoke or flame from the best varieties of it; but it emits a strong, disagreeable, suffocating effluvia when burning.

This coal is very free and tender, and generally breaks small in working and carriage, but it has nothing of the caking quality; it does not burn to a cake or cinder, or produce much ashes.

It is very remarkable, that when a quantity of culm has been on fire in a grate or furnace, and after every particle of it has been burning with a clear glowing heat, when the fire is either extinguished or allowed to go out of itself, what little culm remains in the grate or furnace has no marks of fire on it. Even the surfaces of the small bits which remain unconsumed, retain the same glossy black colour, the same texture and bright appear-

ance as before, and partly of some other species of flaming coals.

6th, JET, which is a peculiar species of coal, is of a fine bright black colour, remarkably clean and light, of a smooth and solid texture, and takes an elegant polish; and, therefore, it is much used in making snuff-boxes and other trinkets.

Jet has a near resemblance of the finer varieties of cannel coal, excepting that the cannel coal has an uniform texture, without any visible grain, and breaks in any direction with equal ease; whereas jet has the apparent grain and structure of wood, not readily breaking across, but it cleaves easily lengthways like the splent coals.

Jet is found in England, and in other parts of the world, in detached separate masses of various sizes lodged in other strata, and likewise in clay pits and in other loose matter, lying above the superficies of the solid strata; but as I do not know of any regular strata of jet being as yet discovered any where, it cannot properly be included in a natural history of the strata of coal.

However, the natural history of jet leads me to imagine that there are strata of it within the solid superficies of the globe, although they are not yet discovered. Samples of all the other species of coal are also found in detached masses of various sizes, lodged in the strata of freestone and others, within the bounds of the coal-fields or coal-coun-

tries; and likewise in the beds and banks of clay, sand, and gravel; sometimes in such considerable quantity as to deceive many, who are led to imagine, from the abundance of this loose coal which they see, that they have discovered the crop or surface of a stratum of coal; whereas it is only a great quantity of detached masses and particles of coal blended in such clay, sand, and gravel, as lies above the superficies of the solid strata. But it is a certain fact, that these samples of coal, which are so found in detached masses and particles lodged in the strata, and in the banks of clay, sand, and gravel in coal countries, are exactly of the same species, texture, and quality as the strata of coal which are found in the same neighbourhood as this loose coal; and, moreover, this loose scattered coal is only found in the neighbourhood of coal, or never far from the coal-fields.

From this fact in the natural history of coal, which every body may observe, I am led to imagine that there may be regular strata of jet as well as of the other fossil coals: Samples of all which are found in like situations and circumstances as the jet, and no doubt they have the same origin, which I have shown above to be the superficies of the regular strata of coal.

This account of the several species of fossil coal which have been discovered hitherto, affords a strong proof, that coal is composed of vegetable

substances, and that the antediluvian woods are the real origin of it.

CHAP. XIII.

OF THE LIMITED QUANTITY OF COAL OF BRITAIN.

I HAVE no doubt that the generality of the inhabitants of Great Britain believe that our coal mines are inexhaustible; and the general conduct of the nation, so far as relates to this subject, seems to imply that this is held as an established fact. If it was not a generally received opinion, would the rage for exporting coals be allowed to go on without limitation or remorse *? But it is full time that the public were undeceived in a matter which so nearly concerns the welfare of this flourishing island.

* This ground of complaint of the waste of coal is now removed. In the time of the Author, the quantity of coal exported to France was very considerable; but this trade being interrupted during the revolutionary war, the inhabitants were led to examine their own resources, which were soon found so abundant as to be equal to the increasing demand of many new, extensive, and flourishing manufactures, in which the consumpt of coal for the purposes of fuel is immense.—EDITOR.

If our coals really are not inexhaustible, the lavish consumpt of them calls aloud for the attention of the Legislature, because the very existence of the metropolis, as well as that of the other cities and great towns, and of the most fertile countries in the three kingdoms, depend upon the abundance of this valuable article; and, moreover, it is the support of our valuable manufactures; and, therefore, if our coal mines are not inexhaustible, it is high time to look into the real state of our collieries.

I feel in myself a strong reluctance against sounding the alarm to my country in a matter of so much importance. I could wish that I did not find myself under the necessity of publishing a truth which to some may perhaps be disagreeable; I could wish that there was some foundation for supposing that I am mistaken; and that it could be made appear with any show of truth, that our coal mines are inexhaustible; but, on the contrary, so far is this from being the case, they are really in many places already making quick advances towards being exhausted. I will not make use of much reasoning in support of this assertion. A few instances in point will be more convincing than a thousand arguments.

Mr Hume, in his History of England, and Mr Arnot, in his History of Edinburgh, place the first discovery of coal in this island about the middle of the thirteenth century; and it appears highly pro-

bable that they are right. Mr Whitaker, in his History of Manchester, places it much earlier, but his proofs are unsatisfactory; and indeed they are such as are to be found in the present or former bed of every river, and in numbers of the gravelly tumuli in all the coal countries; and, therefore, I lay aside his pretended antiquity of this discovery.

As Mr Arnot has been at pains to trace out this subject, and to place it in a clear point of view, I will beg leave to quote a passage from his History of Edinburgh, concerning the first discovery and use of coal in Britain, before I proceed to give any hints of my own about the present state of our collieries.

"As the use of coal claims our attention, both "by reason of its being the most valuable species "of fuel hitherto discovered, and also as an article "of extensive and advantageous commerce, we hope "a short digression concerning its introduction "will not be considered as impertinent. We enter "upon it the more willingly, because we are ful-"ly persuaded that the use of coal was first known "in the period we have described, and that the "date of its origin may be brought within a very "narrow compass."—"Necessity is said, not unapt-"ly, to be the mother of invention. Had our remote "ancestors known that a valuable inflammable sub-"stance was lodged under ground, the abundance "of fuel which wood and turf afforded, would na-"turally prevent them from digging into the

" bowels of the earth for that which its surface so
" amply supplied them.

" Even when wood became very scarce at the
" distance of several centuries after the discovery
" of coal, the manner * of working it was ex-
" tremely rude, the progress and extent of the use
" of it slow and limited. The statutes enacted by
" the Scottish Parliament, and the patents granted
" by the Kings, display their ignorance in work-
" ing coal, set forth strongly its decay, and guard
" anxiously its preservation. In the beginning of
" the sixteenth century, coal smoke † was deemed
" very pernicious, and even in the end of it, the
" use of coal in making ‡ of iron was hardly
" known in Scotland. If the progress in working
" of coal was slow, its first discovery was not very
" remote. Coal certainly was not discovered in
" the middle of the twelfth, and it was as certain-
" ly known in the beginning of the thirteenth
" century. In the *Leges Burgorum*, which were
" enacted § about A. D. 1140, a particular privi-
" lege is granted to those who bring fuel into bo-
" roughs. Wood, turf, and peats are particularly
" mentioned; but with respect to coal there is a

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* Mary, Parl. 9. c. 84.

† Northumberland Household Book, p. 21.

‡ Patent by James VI. A. D. 1594, in the Archives of the Earl of Balcarras.

§ Leg. Burg. c. 38.

" dead silence. But, in the year 1234, Henry III. " of England * renews a charter which his father " had given to the inhabitants of Newcastle; and " in this renovated charter, he grants, upon their " supplication to the persons in whose favour the " charter was conceived, licence to dig coals upon " payment of L.100 a-year, which is the earliest " mention of coal in the island. By the end of " the thirteenth century, the use of coal was so " much advanced, that it was frequently brought " by sea carriage † from one port to another. But " the first mention that is made of coal in any " charter in Scotland is in a grant executed, A.D. " 1291, in favour of the Abbot and convent of " Dunfermline ‡, of the privilege of digging coal " in the lands of Pittencrieff, in the county of " Fife.

" Æneas Sylvius, who afterwards assumed the " purple under the name of Pius II. visited this " island about the middle of the fifteenth centu- " ry. He relates, 'That he saw in Scotland § the " poor people, who in rags begged at the churches, " receive for alms pieces of black stone, with which " they went away contented. This species of " stone (says he), whether with sulphur, or what-

* Anderson's Origin of Commerce, vol. 1. p. 111.

† Statuta Gildæ, c. 44.

‡ Cartulary of Dunfermline, p. 80. Advocates Library.

§ Æneï Sylvii Opera, p. 443.

" ever inflammable substance it may be impreg-
" nated, they burn in place of wood, of which
" their country is destitute.'

" And Boetius, in his Description of Scotland,
" his native country, written in the beginning of
" the sixteenth century, says, ' There are black
" stones also digged out of the ground, which are
" very good for firing; and such is their intole-
" rable heat, that they resolve and melt iron, and
" therefore are very profitable for smiths and such
" artificers as deal with other metals * ; neither
" are they found any where else (that I know of)
" but between the Tay and Tyne within the
" whole island.'

" In China, it is probable that coal was disco-
" vered long before it was known in the western
" world.

" About the middle of the thirteenth century, a
" noble Venetian, in his Description of China, ob-
" serves, ' That through the whole province of † Ca-
" thay, certain black stones are dug out of the
" mountains, which being put in the fire, burn like
" wood; and when kindled, they continue burn-
" ing a long time, in so much, that if they are
" lighted in the evening, the fire will keep alive
" during the whole night. Many use these stones,

* Boetii Scotorum Regni Descriptio, p. 10.

† Marcus Paulus Venetus, Purchas's Pilgrim. vol. 3. p. 83.

" although they have plenty of wood, the con-
" sumption of fuel in stoves being very great.'

" It is curious to observe the similarity with
" which Marcus Paulus, Æneas Sylvius, and Boe-
" tius speak of the same matter."

Upon the whole, we have little hesitation in fixing the discovery of coal to have been made between the middle of the twelfth and beginning of the thirteenth centuries.

Although it appears to be full 400 years since coal was first discovered in Britain, yet it is not above 200 years since it came into common use, and it is even less than 200 years since it came to be generally used in London.

Upon the first introduction of coal into London for common uses, one or two ships was sufficient for the whole coal trade; but from this small beginning, the trade has gradually increased, so as to require several thousand sail of shipping from the ports of Shields, Sunderland, and Blyth only, and some of them are of vast burden, even up to a thousand tons, and many of them make several voyages a-year.

Such a number of ships continually carrying coals from Newcastle, Sunderland, &c. not only to the metropolis and other places of England, but also to almost all parts of Europe and America, must drain away an immense quantity of coal from the neighbourhood of Newcastle. Dr Campbell, in

his Political Survey, says, that in his time 600,000 chaldrons of coals a-year were consumed in London alone; and, as the bounds of the metropolis are greatly increased, we may safely conclude that the consumption of coal in London is also increased, at least one third, if not fully doubled, since he wrote his Survey; and the consumpt of London, though great, is nevertheless but inconsiderable in comparison of what is carried from Newcastle and its neighbourhood round the coasts of Britain, and to other parts of the world.

The run of coals from Newcastle and Sunderland has been so very great for above fifty years past, that we need not be surprised if we were to find the coals considerably wasted in the neighbourhood of Newcastle, so as to be in danger of soon raising the price considerably to the metropolis, &c.; and in fact this is the case. The coals near the sea in the neighbourhood of Newcastle are already wasted to a great extent, and to such a depth, that they cannot conveniently and profitably go much deeper; and, therefore, we may safely conclude, that a considerable rise in the price must happen at no very distant period.

Some of the coal pits of Newcastle are one hundred and twenty fathoms deep, and the powers of the fire-engine are so much increased, that it may be said to draw a river from that vast depth; but these powers cannot be increased much farther, without a considerable increase of expences.

These circumstances clearly prove, that coals are so far wasted near water carriage in the neighbourhood of Newcastle, that they are become already very difficult and expensive to winn: as a proof of this, coal is now wrought for sea sale near twenty miles up the country from Newcastle, and this coal is brought to the water upon waggon-ways, or roads composed of frames of timber, which are made and upheld at a vast expence.

It is not above thirty years * since the Carron Company founded their great iron works in Scotland; but in that time they have consumed an immense quantity of coal.

Several of the coal seams at Borrowstounness and Grange, in Scotland, are greatly wasted, and the works are pretty deep, and the coals are worked at considerable expence with large fire-engines in several other places upon the banks of the Forth. The cities of Edinburgh and Glasgow depend upon the fire-engine for their supply of coals; and yet they ship away from Glasgow all the coals for which there is a demand, without any apprehension of the future.

At Whitehaven, which chiefly supplies the city of Dublin, and many other parts of Ireland, with coal, it is dug out at the enormous depth of more than a hundred and twenty fathoms; and, of con-

* The Author wrote in 1789.

sequence, great part of the coal easily accessible is exhausted, and what remains must be worked at great expence.

I will only point out another place where the coals are exhausting rapidly, and the scarcity and dearth of them, I fear, will soon be felt by many of the commercial cities and industrious inhabitants of Britain. The island of Britain is famous in the earliest records of history for the tin mines of Cornwall; and to this hour, they are of great consequence to its manufactures and commerce; but the tin mines especially have been worked so long, and, of consequence, are now so deep, that very little of that valuable metal can be raised without the fire-engine. But, alas! they have no coal in Cornwall. All the coal necessary for working the fire-engine, and for their smelting furnaces, is brought by sea from South Wales. I am not well informed either of the extent of the coal-fields, or of the proportion of coal already wasted in South Wales; but from such information as I could get, it appears that the coals there are wasting rapidly; and what will become of the mines of Cornwall when they are exhausted? I have been informed that the price of coals in South Wales is already so high, that several Cornish mines are now standing, because they cannot be carried on with profit while coal is so dear; and if coal rises to a higher price in Wales, which very probably will happen in a few years, it will

be equal to a prohibition from working most of the Cornish mines. When this event happens, what will become of many of our valuable manufactures, upon which much of our lucrative commerce depends?

This is a mortifying view of the subject, but I am afraid it is too just a representation; and yet, as far as I know, this interesting subject has never been considered in this light, or has any person, public or private, to the best of my knowledge, ever taken the trouble to make a fair representation of this matter to those whose province it is to examine and remedy such evils. There is no restraint upon the unnecessary consumption of coal, however many and important the manufactories which depend upon it for fuel.

If the consumpt and waste of the coal of Britain be so great at this early period from the first beginning of the general use of coals in this island; if it be so much exhausted, and raised to so high a price, in little more than two hundred years from the first use of coal, and in less than one hundred years from the commencement of an extensive consumpt, what may we not suppose will be the price two hundred years hence?

The coal trade, and the general use of coal, have so increased, that I am persuaded that the one half of all the coal that ever was consumed in this island, and exported from it, has been raised within the last eighty years, as there was, compa-

latively speaking, but little coal used eighty years ago. And if this be true, it shows us how rapidly our coal is wasting; for it is certain that our coal works in many places are deep, the coal wastes extensive, the machinery and whole apparatus of the works very costly, and the coal, in maritime places especially, raised at a great expence; so great indeed, that some coal works are carried on with loss.

When our coal mines are exhausted, the prosperity and glory of this flourishing and fortunate island are at an end. Our cities and great towns must then become ruinous heaps for want of fuel, and our mines and manufactories must fail from the same cause, and then consequently our commerce must vanish. In short, the commerce, wealth, importance, glory, and happiness of Great Britain will decay and gradually dwindle away to nothing, in proportion as our coal and other mines fail; and the future inhabitants of this island must live, like its first inhabitants, by fishing and hunting.

My natural history of the strata of coal may be disputed by such as are absolutely ignorant of the subject, but it cannot be disproved by those who will take the trouble to examine all circumstances; but whether it be disputed or not, the general facts which I have stated relating to the subject of our collieries and of our coal trade are incontrovertible; and these facts are easily investigated. Accu-

rate surveys can be made, and pretty near calc lations of the coal to be had, and of the time will last, when compared with what has be worked out of each coal-field for a limited ti past. Now, if these facts shall, upon due exa nation, be found as I have represented them, I w leave it to disinterested well-wishers of their cou try to judge whether or not this subject deser and requires the attention of the public.

I am no judge of the lawfulness or propriety restraining the subject from the uncontrouled of his property in this land of freedom; bu clearly foresee the fatal consequences to fut ages of a too rapid consumption of our coal, es cially in the maritime parts of the country.

It is well known to many, though perhaps sufficiently considered by the public in gene how much this nation is indebted to the mine kingdom for the principal commodities which conveyed round the globe in the numerous a extensive channels of our commerce.

The manufactories which prepare the materi and fabricate these commodities, are exceedin multiplied and various, and the number of hu employed about our mines, manufactories, a commerce, is very great; and it is an establis truth in politics, that numbers of people well e ployed are the riches of a nation; and it is es cially so in this case, as all the materials from mineral kingdom are our own. Our other mi

produce the raw materials of our various manufactures of hard ware; but some of those materials cannot be raised out of the mines, and none of them can be prepared and manufactured without coal.

I have no abilities for nice and extensive calculations, or what is called political arithmetic; but there are some plain facts which appear to me very evident, and must appear so to every other person who takes even a cursory view of these matters: Such as, for instance, 1*st*, The lower the price of coal is, the cheaper the crude materials from the mineral kingdom can be prepared, and the cheaper the commodities can be manufactured from them: 2*d*, The cheaper our commodities can be manufactured, the better we are enabled to rival other nations in commerce: 3*d*, While we have coal enough at a moderate price, our manufactures and commerce will continue to flourish; but it is impossible that they should flourish any longer than our coal is plenty and reasonable; because other nations have greatly the advantage of us when our coal is either exhausted or too dear, as most of them have a much greater quantity of wood than we can boast of, or it would be our interest to have: 4*th*, There are plenty of productive mines of all the British metals upon the continent of Europe, which they cannot now manufacture into such a number, quantity, and variety of excellent commodities as we can do, on account of the plenty and excellence of our coal; but when

our coal fails, or becomes too dear, then they can rival and exceed us on account of their extensive woods.

These facts are plain and self-evident, and therefore need no illustration: but they certainly call for attention; and it would require extensive knowledge, wisdom, and skill to form such regulations as will favour our own manufactures, and at the same time do justice to the subjects and to the revenue of Britain.

The city of London, and the other cities and towns upon the east and south coasts of England, seem to me to have a strong claim, if not a natural right, along with our manufactories, to all the coal which the north of England can produce; and if proper care is not taken of their right in due time, they will too soon be deprived of it. There is indeed a pretty good fund of coal in Fife, and other places upon both sides of the Frith of Forth, which may be sent to the metropolis, and to other places upon the east and south coasts of England; but there are many manufactories upon the banks of the Forth, which would be soon hurt by such a trade, in consequence of which, the price of coal would soon become too high; and, moreover, the north of Scotland depends upon the Frith of Forth for a supply of coal, and seems to have a natural right to all the coal that can be spared from thence.

The mines of Cornwall and our copper manu-

factories, and such other manufactories in the west of England as use tin and copper, seem to me to lay claim to all the coal that can be spared from South Wales, as indeed those mines and manufactories are of the first consequence to great numbers of British subjects, and to some important branches of our commerce and revenue.

The city of Dublin, and many other parts of Ireland, depend upon Great Britain for a necessary supply of coal, even for culinary uses; and I hinted before, that the collieries of Whitehaven, from whence Dublin is chiefly supplied, are already very deep. There is, however, a valuable and extensive magazine of coal for Irish consumption treasured up in the county of Air; and it is well for Dublin, and other parts of Ireland, that there are such magazines in Airshire and the north-west of England; for what would become of Dublin, &c. should this coal fail?

Restraints imposed upon any established branch of our export trade, however salutary their tendency to the community in general, and the national manufactories in particular, would, nevertheless, be interpreted by many as an infringement of the freedom of commerce, and of the liberty of the subject, to dispose of his own property to the best advantage. But another great difficulty still occurs. Any restraints imposed upon the exportation of coal, would in some degree affect the revenue for some time at least. This difficulty seems

to stand as an insurmountable barrier in the way of the future welfare of the people and manufactories of Britain with respect to cheap coal, and yet cheap coal is absolutely necessary for the welfare of both.

I am not politician enough to be able to suggest the proper remedy for these difficulties; but I will beg leave to observe, that, in my humble opinion, the coal of Cape Breton, and other parts of the western world in our possession, may be brought to make good the deficiency which the revenue might suffer by diminishing the export of coals from Britain. But I shall farther consider this subject in the next Chapter.

CHAP. XIV.

OF THE COAL OF CAPE BRETON AND NEWFOUNDLAND.

I AM not sufficiently informed of the history of the coal of Cape Breton, &c. to be able to state the circumstances relating to it with any degree of precision; in general, however, it appears certain, that there is abundance of coal in that island, and that some of it was wrought by the French, and exported to their sugar islands.

Several navigators who had been at Louisbourg, assured me that the island abounds with coal to such a degree as to appear in the cliffs near the harbour; but as none of them were men of science in this branch of natural history, their account was vague and unsatisfactory. Abbé Raynal's account of this coal, in his History of the Settlement and Commerce of the West Indies, is not less so.

In general, I learn from Raynal, that the coal lies in a horizontal position; that the French wrought it very near the surface without any hydraulic machinery, and even without any level mine or adit for draining off the water. It is probable that they began upon a stratum of coal in the face of one of the cliffs, and wrought it under cover, which is commonly done in Britain when coal is discovered in a cliff, or a ravine, and wrought upon a small scale.

Raynal's account of this matter, or any other information I have yet procured, gives no grounds for apprehending that any considerable quantity has been wrought. Such a work as Raynal hints at, could have produced but very little coal that was worth raising at all. It is very well known to men of skill and observation, that such parts of every stratum of coal as are very near the surface of the ground, and as are naturally drained by the figure and disposition of the surface, is seldom good for any thing; and it seems to say

much in favour of the Cape Breton coal, that those superficial works produced such as was worth the raising.

We are farther informed by Raynal, that a seam of coal was set on fire at Cape Breton, which burned with great fury. As this accident may seem very alarming to such as are unacquainted with these matters, it may be proper to observe, that this conflagration cannot be of very dangerous consequence to the coal. It will only consume the stratum that is on fire in the horizontal direction, until the fire arrives at one of the natural bars, which are so frequently found to interrupt the regular stretch and bearing of the strata, known by the names of dykes, slips, &c. and there it will be stopped, for there the stratum of coal is partially cut off. It will only consume the seam of coal towards the dip or declivity of the strata to the water's edge, that is, so far down as the seam of coal is naturally laid dry by the cliffs and ravines, and other inequalities of the surface of the ground; and when it only burns down to the water, it is sure to leave the best of the coal; for experience shows, that the deeper coals are wrought down under water, the better they always prove. It is proper to observe, that while a coal is burning near the crop or surface, it is not prudent to open any works to the dip upon that seam until the fire is entirely extinguished, because the fire will communicate with the works below when it gets air,

and destroy the whole. However, in cases of necessity, the fire may be got under, and wholly extinguished, by stopping the mines and shafts, and other apertures and air vents; and the effect will be hastened if a rivulet can be turned into the burning cavities, and such stoppages made as will confine the water to rise within the excavations. But if the external air can be perfectly excluded, the fire will be extinguished without farther trouble.

As the island of Cape Breton is of considerable extent, and as there is a certainty of coal existing in the island, there is great probability that it may prove a valuable coal-field. There is but a narrow straight between Cape Breton and Nova Scotia, and the latter is situated directly in the line of bearing of the strata; so that it is probable coal may be found in the maritime parts of Nova Scotia. Indeed, it is said, that it really has been seen there; and it is also said, that coal has been discovered in the island of Newfoundland; one or both of which places may turn out well, if properly tried. But supposing they should not, Cape Breton is of such considerable extent, that it promises a fund of coal equal to a very extensive exportation, and to the demands of the New World, for a long period of time, there being no room to doubt the existence of a number of seams of good thickness and quality.

This subject appears to be of such importance

as to merit an inquiry, whether or not it is proper for Government to encourage the working of those coals upon a large scale? In my humble opinion, it cannot admit of a doubt that it would be highly proper; and in the event of this new trade proving successful, it would soon become greatly beneficial to the mother country, by keeping down the price of coals at home, which would encourage her manufactures, as well as by drawing a revenue from the foreign coal trade.

It is not improbable that this scheme would meet with some opposition at first from the wealthy coal-owners of Britain, as it might excite in them an apprehension of some abatement of their profits, as they now ship a considerable quantity of coal for the western world; and it must be confessed, that if the existence and prosperity of the British empire were only to last for the short space of thirty or forty years, commensurate to the time that a set of men may be fit for pushing a lucrative branch of business successfully, and that at the end of that period all was to sink in oblivion when those men die, it would be very proper to hear them.

Upon such a supposition, it does not appear that any real good to Britain could be proposed from opening American or West India coals, because there is at this time a considerable quantity of coal carried from Britain to the West Indies and America; which branch of trade the Ameri-

can coal would interfere with and diminish. Self-interest acts upon the principles and views of present profit, and neither cares nor considers what will be the future consequence to posterity, provided it reaps the present advantage; but God forbid our British rulers should at any time be so unconcerned about the present and future welfare of this island, as to leave undone what would hurt and injure the community in general, to gratify the avaricious views of a few wealthy individuals.

Upon this supposition of the coal of Cape Breton being opened, and proving as successful as there is reason to hope and expect, the coasts of the West India islands and of the continent of America are so very extensive, and the cities and towns upon the coasts so numerous and considerable, that the trade in that coal might be enlarged to such an extent as in time to bring in a revenue to the British Treasury, equal, if not superior, to the receipts from the whole coal trade of Great Britain, without laying too heavy a duty, or any way oppressing the western trade.

This event of itself is devoutly to be wished by every disinterested British subject; but it is not this consideration that lies nearest my heart. It appears to me certain, as an infallible consequence of the nature of things, that the commercial wealth and glory of this industrious and happy island must dwindle away by degrees, in proportion as

coals become scarce or rise in price, and disable us from keeping down the prices of our manufactures, at least upon a par with our rivals; and, therefore, it is the saving of our own coals for our own use, and for the public good, that should be our chief motive to open the West India coal; and, moreover, it may not perhaps be improper to work out those coals as soon as possible, while they are in our power, lest we should not have them to work in time to come, if we let slip the proper opportunity, which seems to be now in a time of peace, when we have leisure to look after such matters.

We see, that with the help of our rivals, thirteen of the American provinces are made independent, and it is probable that they will soon be formed into a great empire. Many of the inhabitants of the principal cities of America have burned British coals for a considerable time past, which they found cheaper than wood, after the country began to be cleared near the sea-coast, notwithstanding that the purchase, duty, and freight of coals from Britain must raise the price of them prodigiously to the Americans. I do not know that there is much coal, if any, as yet discovered within the territories of the States of America; and, therefore, it is to be supposed, that as they gather strength, and feel more the want of coal, they will cast an evil eye upon Cape Breton, &c. and envy us the possession of an island in their neigh-

bourhood, which seems to be a vast magazine of coal.

Fire-wood will soon grow scarce and dear along the coasts of North America, and manufactories will soon be established there, which cannot be properly and effectually carried on without large supplies of coal; and, therefore, we must suppose that the very sense of their wants will alone be sufficient to make a conquest of Cape Breton, for the sake of our coal. Such a conquest might be accomplished and secured before we in Britain could be well apprized of the preparations for it; but if we had flourishing and extensive collieries, and a brisk coal trade going on there, in conjunction with our fisheries, it would be better worth our while to keep the island in a more sufficient posture of defence than it is at present. In short, I am of opinion, that the sooner those coals are worked the better.

The certain knowledge of a fund of coal lying there unwrought, may be the means of losing all our West India possessions on account of those coals. It is not only the Americans that stand in need of them. The French, &c. are also much in need of them; and why may not the French join the Americans to conquer the rest of our American possessions, when they find by experience that the coal is absolutely necessary for both? We know what they have done, when they had no other motives, in procuring independence

to our colonies, than to weaken us, and to appropriate our American trade to themselves; and why may they not do the same again, when they have the additional motive of securing to themselves our coal mines and fisheries, which are by far more precious to a manufacturing commercial people than gold mines?

If we could give the Americans a plentiful supply of coals from Cape Breton, it is presumed, that they would find this to be so great a national convenience, that it would induce them to extend their trade with Great Britain in preference to all other countries.

As matters now stand, no other nation can supply them with this precious and necessary commodity; and all people feel themselves happy when their wants are supplied. Our supplying them with coal must, as a natural and necessary consequence, turn the balance of trade to our side. They will give the preference to our commodities for the sake of our coals, which no other nation can supply them with; and, therefore, we can keep the balance in our favour so long as we keep all our present possessions, and make a good use of them.

It has been said that there are coals in Canada; but as far as Professor Kalm of Sweden had an opportunity of viewing the superficies of the strata in that country, no appearance of coal was observed: And his account of the strata which he

saw in a journey from New York to Montreal, along the margin of some of the lakes and rivers, and along a considerable part of the river St Laurence, is judicious and satisfactory; but Mr Kalm saw not the least symptom of coal in all that country.

I am fully sensible that my information is not so perfect as the magnitude and importance of this subject deserve: Nevertheless, I think it my duty to communicate such hints as are in my power; and however imperfect my hints are, I cannot help thinking that their great importance merits the attention of Government; and this attention will produce proper inquiries, which will enable them to investigate the truth of the facts which I have hinted at; and such inquiries will give them the knowledge of many circumstances relating to this subject, which at present are out of my reach.

The farther I look into this subject, the more interesting it appears. The existence of abundance of coal in the island of Newfoundland is generally understood to be an established fact. This is still a more interesting situation for coals than Cape Breton, on account of its vicinity to the great fishing bank. Cape Breton may be called the key of Canada, but Newfoundland is the asylum and defence of the cod fishery; and the importance of this great nursery for sailors, is very great to a maritime and commercial nation,

whose natural and surest defence is her naval force.

In the light which this subject appears to me, it is to be wished that the coals of Newfoundland, as well as those of Cape Breton, were worked out by us.

An extensive and successful coal trade at Newfoundland and Cape Breton, would produce such an increase of commerce and revenue, as would make our possessions in the west a great and constant object of care and attention. Our coal ships and other trading vessels would be continually traversing the coasts of the islands and continent of America. They would have something to do in every creek and harbour, north and south, which would give us perfect intelligence of what is going on in all the regions of the New World; and, therefore, we could never be surprised; and, as a consequence of the increase of commerce, we should always have a greater naval force in the West Indies than present circumstances require.

The Americans have plenty of timber for shipbuilding, and for making charcoal for smelting their own iron ores. They have plenty of good land fit for raising hemp for cordage and sail-cloth; and abundance of these articles in perfection will put it in their power to build ships of war at a cheaper rate than we can do. It is vain to imagine that they will not some time or other avail themselves of the advantages of their situation, of

the fertility of their soil, and of the natural productions of their country; and it is as vain to imagine that they will not cast an evil eye upon our western coal mines and fisheries, when they have fully settled their form of government, and feel their own strength, and their want of our possessions, for the farther increase of their manufactures, commerce, and wealth, and the farther aggrandizement of their power.

When Government is fully satisfied of the value and importance of the American coals, of course it becomes a serious question, what is the most proper plan for opening and working those coals, for the interest of the nation and of all concerned?

A few hints upon a subject of so much consequence, from a professional man, cannot be thought unseasonable.

In discussing this topic, we presume to suggest, that, in the first place, it is necessary for Government to explore and discover these coals, and lay them bare, for the inspection of British coal masters or companies: and with this view, the first thing to be done, is to employ a prudent man of abilities and skill in the theory and practice of the coal business, to survey the American coals and coal-fields; to make such trials upon the coals already discovered, and those he may discover, as may be necessary to ascertain the thickness, quality, and situation of each stratum of coal that

may be judged worth attention; and to make out a full and substantial report of all the material circumstances relating to each coal, for the information of Government, and of such individuals and companies as may wish to look into this interesting subject.

As far as circumstances can be investigated, his report should give a satisfactory account of the quality and thickness of each seam or stratum of coal; of the number of workable seams in each coal-field; of the roof and pavement of each stratum of coal, and the other concomitant strata situated above and below each coal, so far as they can be seen, and of the slope or inclination of the several coals from the horizontal position. He should consider the ease or difficulty of sinking upon, and of winning and working each stratum of coal; what machinery will be necessary for that purpose; the distance from a good harbour or shipping place; the ease or difficulty of conveying the coals to the shore, and of shipping them; and the present condition, and necessary improvements, of the several descriptions of shipping places, should come under his consideration. He should calculate and report his estimate of the expence of opening and winning such a seam or seams of coal in Britain to a proper depth, and upon a proper scale, to be ready to work with a sufficient number of colliers, including the necessary machinery, and how much per ton is com-

monly paid the colliers in Britain for working such seams of coal.

When this report is made and considered by Government, suitable encouragement should be offered to gentlemen, and to companies of character, stock, and abilities for such undertakings, to open and work some of those coals. It might be prudent for Government to give some aid at first to the undertakers: but such works would not thrive if carried on at the public expence; they must be carried on by frugal and skilful undertakers, if we would expect them to succeed; and it will be necessary for one at least, and a skilful one, of those concerned, to be always upon the spot.

The first undertakers should be allowed a sufficiently extensive coal-field, and every reasonable privilege and indulgence; but they should not have a monopoly. Other adventurers should have room to employ their skill and capitals in this line of business in the west as well as in Britain. Monopolies seldom do much good. The views of monopolists are always too selfish and confined to be of extensive utility and public benefit.

Newfoundland, Cape Breton, and the peninsula of Nova Scotia, are all in the true line of the bearing of the strata of coal, and others in the same parallels of latitude in other countries. The strata of Great Britain, and those in the same parallels of latitude of other countries, trend from north-east

to south-west, or nearly so; and, from viewing the map, it appears that Newfoundland, Cape Breton, and Nova Scotia, are situated in this line of bearing; and, therefore, it is probable, that the same coals and coal metals stretch through these three different countries. There seems to be a certainty of plenty of coal in the two islands, and it is probable that the coal of Cape Breton stretches through the narrow strait into the peninsula of Nova Scotia, which is but a short distance.

The discovery of abundance of good coal in these three countries, will give ample room for a number of undertakers: But supposing they were only found sufficiently good and plentiful in one of the three countries, there will still be room enough for a number of adventurers, and for a very extensive coal trade. How many different collieries of great extent are wrought in the two counties of Northumberland and Durham in England? And most of the coals of those counties are shipped off in the two ports of Shields and Sunderland. The populous sea-coast of North America is so extensive, and the cities and sea-ports upon that coast are so numerous and flourishing, that there is no room to doubt of a sufficiently extensive demand to excite the activity and exertions of a number of adventurers in the western coal trade, besides the demand of the Carribbee Islands, which of themselves are sufficient to create a brisk trade.

In the event of a brisk coal trade in the West Indies, Halifax or Louisbourg will soon become a famous mart, the staple of a great and extensive commerce, which will be created by the coal trade. Canada and Nova Scotia will share with the mother country the benefits of the new commerce of the west. A new and powerful spring will be given to the agriculturists. Their rich and extensive soils will receive the highest improvements, by supplying with provisions the numerous shipping and increased population which this new commerce will soon create.

Commerce gives the means and necessary aid for improvements in agriculture; but agriculture itself is the foundation of the commerce and prosperity of all nations. Agriculture gives to commerce men, provisions, and a great part of naval stores; and commerce supplies the means of improvements in agriculture. If Canada and Nova Scotia were favoured with these aids to improve their lands, the rich soils of those countries might soon come to supply Great Britain with all her naval stores. The woods of Canada and Nova Scotia will supply masts, yards, and tar; and their fertile soils will supply abundance of hemp, when they are enabled to advance the improvements of those soils. With respect to iron, there is now a considerable quantity made in Great Britain; and, to my certain knowledge, we have abundance of the raw materials for making any quantity that

might at any time be desired. If a small encouragement was given for the making of iron at home, and some discouragement to the importation of foreign iron, our furnaces and blomaries would soon increase to such a degree as to produce a sufficient quantity to answer all the demands of agriculture, manufactures, and shipping; and this regulation would have a direct tendency to enrich the nation, by keeping the money at home, in circulation, which now goes abroad to enrich other nations, and by employing great numbers of our own people to work upon our own materials. Our own iron manufactories certainly merit the public attention.

The British coal trade is well known to be an excellent nursery of able and hardy seamen. Few naval scenes in the world, if any, are more active and more constant than the coal trade from Newcastle and other parts of Britain; and it is where they are constantly employed in rough and dangerous seas, like the coasts of Britain, which always require hard labour, that able and hardy seamen are bred; and these, on board our ships of war, under able commanders, are the glory and defence of the British dominions.

The coal trade of the west, when it is improved, and the other branches of trade which it will create or increase, will employ and breed many thousands of good and hardy seamen: Our dominions in the western world will then become active

and flourishing upon the American seas, like the coasts of Great Britain, and our mercantile shipping will form a bridge of ready communication between the Old and New Worlds.

But whatever may be the fate or the success of the American coals, it will not lessen the consequence of our own, or the necessity of looking into the real state of our collieries; because it is of the utmost importance to the metropolis, and our other trading cities and towns, that there should be a certainty of the continuance of a plentiful supply of fuel at a moderate price. It is of the utmost importance to the prosperity of our manufactures that this fuel should be cheap; the prosperity of our commerce immediately depends upon our manufactures; and both must dwindle and decay in proportion to the scarcity or the high price of our coals.

It is of great consequence to our manufactories, that coals should be plenty and cheap near the site of such as are already established, and where new ones are to be set a-going; because, in most instances, the crude materials will not admit of being carried to the coals, and therefore the coals must be carried to them; or, in other words, remote country places, at a great distance from the sea, will not answer for the site of most of our manufactories, and therefore it would greatly injure them to have the price of coals raised too high in maritime situations, where such manufac-

tories are and should be established and carried on; and they will too soon be raised high, if some proper regulations are not made in time to prevent it.

I do not know that the nation is much enriched by the money our coals are sold for in foreign countries; but I know that the increase and prosperity of our manufactures and commerce enrich the nation, because our own productions are thereby used to the best advantage, and our own people are employed; and it is the number of people well employed that brings solid riches to all nations; and I apprehend that it is yet practicable to increase our manufactures considerably.

I know certainly, that in many places our metallic mines are not worked to the extent to which they might be carried on with profit; but dear coals must throw a prodigious damp upon mining, because the steam-engine is now become necessary to mining at any considerable depth, which cannot be worked without cheap coals, nor can they afford to manufacture the crude productions of the mines if the coals are too dear.

There is much money sent out of the nation for bar iron, and yet we have plenty of materials at home for making iron: And I can prove to ocular demonstration, that there is great abundance of the richest iron ores and iron stones to be had in Scotland especially, and which can be raised at

very moderate expences, where coals are also abundant and reasonable.

A greater number of blomaries would increase the number of useful manufactures; and the national advantages of the increase of useful manufactures is a subject which has been frequently explained: and, therefore, it would be idle and impertinent in me to proceed any farther, than barely to state these brief hints relating to the connection and dependence of our manufactures upon coal.

PART II.

OF THE NATURAL HISTORY OF MINERAL VEINS, AND OTHER REPOSITORIES OF THE USEFUL METALS.

In this Part we shall treat of mineral veins of some other situations and circumstances of the mineral ores, and of the most promising and certain appearances and indications of valuable mines; and we shall also point out some local examples of new mining fields, which deserve to be explored.

There are at least four distinct species of mineral veins, viz. 1*st*, The *rake vein*, or perpendicular mineral fissure; 2*d*, The *pipe vein*; 3*d*, The *flat* or *dilated vein*; and I will venture to add a 4*th*, Which I call the *accumulated vein*. These different kinds of veins, with the most important circumstances connected with them, will form the subjects of the following Chapters.

CHAP. I.

OF RAKE VEINS.

THE rake vein, called by naturalists the *perpendicular mineral fissure*, is the most common and best known among practical miners. The rake vein, in mining, is the same species of perpendicular fissure as was described by the name of *slip* in the coal metals. They have both the same origin and natural cause; they are both of them a longitudinal gash, rent, or opening in the rock and strata, commonly running in straight lines. This gash or fissure cuts all the strata and rock quite through from the surface, as far down towards the centre as the vein dips, which is generally out of our reach, and as far forward in the line of bearing as that vein reaches. I say, the rake vein is a longitudinal gash or fissure, commonly in a straight line, which begins at the superficies of the strata, and cuts the rock and strata asunder, generally farther down than we can reach. Sometimes this vein stands nearly perpendicular, but it commonly hangs with less or more slope, which slope is called by miners *hading*, or the *hade* of the vein. I said that the

rock is cut asunder by this fissure; and the rock upon the sides of the gash is called the *sides of the vein*, and these sides are called by miners the *hanging side* and the *ledger side*, or briefly the *hanger* and *ledger*. Some miners call them the *hanging side* and the *hading side*, and the longitudinal line to which the fissure points, is called the *bearing of the vein* *.

Of these perpendicular fissures or rake veins there are two species. The origin of one of these, as I hinted before, is a crack or rent, and a slip of the strata, and the other is a gash or chasm in the rock without a slip: the sides of the gash are separated and opened asunder; but the edges of the strata upon both sides of the fracture continue opposite to one another, so that there is no slip. This distinction or different species of vein is not commonly known among miners or mine-masters, as they are less accustomed to examine all the phenomena of the strata. It is in the collieries that all these things are carefully examined and investi-

* To enable the reader distinctly to understand these terms, let it be supposed that a vein runs in a direction from north to south, with an inclination to the east, and forming an angle of 60° with the horizon as it dips downwards. The *bearing* of such a vein is north and south; and if a person enter the vein from the south, the *hanging* side, or the hanger, is on the right hand, and the *ledger* side, or ledger, is on the left hand.—Editor.

gated. The miner is careful to investigate every circumstance relating to his vein, but is very little concerned about the regularity or irregularity of the strata; on the contrary, the collier is chiefly concerned with the regular strata, and he is only obliged to investigate the veins when they occur to him as slips or gashes, in order to know how to get the better of them.

I will point out some distinguishing marks or characters of each, to enable the miner to know the one from the other when he is working them. The slip veins are seldom wider above than below, but are generally narrower, that is, the sides of the fissures are closer together above at the superficies of the strata than farther down. The slip veins are very subject to checks or twitches, so called by miners, when the two sides, or hanger and ledger, come close together, and no cavity or open space is left between them, so that there is no room for any material quantity of ore to be lodged in a twitch.

There are many of these checks in all this species of rake veins, which continue for several feet or for several fathoms; and the cavities or openings between the several twitches are wider or narrower, longer or shorter, at all possible uncertainty. The sides of many of the veins are very close together above at the superficies of the strata, which, nevertheless, open to considerable but very different degrees of wideness below; and these

openings are called the bellies or cavities of the vein; and again, many of them are found regular and uniform, and carry a good rib of ore for a considerable length upon the bearing of the vein, and others may carry some ore, and good enough mineral soil in small quantity, and yet never open at all to do any good. The gash veins, on the contrary, are always wide above, and grow narrower, or the sides come closer together, as we work down in them at uncertain depths, and they often close or check out below altogether. The gash vein is not so subject to twitches in the line of bearing as the slips, but it is frequently crossed and intersected by whin dykes or bars of hard stone, which generally shove it a little to one side, off the true line of bearing; and I believe it may be asserted of them, that they always carry most ore above pretty near the surface; whereas, on the contrary, the rake or slip veins are generally widest betwixt the sides, and carry most ore below at a considerable depth from the surface.

There is a remarkable mineral vein, of the species I call a *gash*, at Strontian in the Highlands of Scotland. All the rocks in the mining field at Strontian are a grey granite, which is called *moorstone* by the Cornish miners. Several veins at Strontian were opened first by the York Building Company, and a considerable quantity of lead ore was raised by them.

The principal vein at Strontian is perhaps the

strongest mineral vein as yet worked in any part of Britain. In this vein the York Building Company found a large body of exceedingly good ore at first, putting up to the day, which they worked out open-cast, that is, their works were cut up quite open to the day, like a large longitudinal trench or gulph, the vein being exceeding wide, and they did not mine it under cover at all. This open-cast has been worked to a great length upon the bearing, and the old works now exhibit a horrid and frightful gulph of great length, and several fathoms wide.

This large vein or chasm in the rock must have happened when the whole mass was humid, before the rock was thoroughly indurated; I say rock, because there is not here the least appearance of regular strata, or of any stratification at all; the whole mountain being one prodigious mass of grey granite, in which there have been at first a great many cracks or gashes besides this vein, as may be seen by the other mineral veins and the great number of whin dykes in this mining field; which dykes cross, intersect, and disturb the mineral veins in many places, and are frequently seen upon the surface; these extensive rocks being mostly all bare, and washed clean by the heavy rains so frequent in that country.

Tradition says, that the York Building Company had a rich vein of solid lead ore here, at first of four or five feet wide, quite up at the surface

of the ground, besides several feet wide of ore, mixed with spar and vein-stone; and the appearance of the old man, that is, of the old works, seems to confirm the truth of the tradition, the old works being exceedingly wide at the surface, and for many fathoms down. Indeed I can see no reason for working so wide, had they not found the ore as wide, the stony parts of the vein where the ore is not so good being sufficiently strong and firm; and, moreover, we do not see any great quantities of waste or rubbish, but such as the washing and dressing of the ore have produced, which is a clear proof that they had some ore, solid or mixed, in the whole width of the old works.

The lead ore of Strontian is of the species called *potters ore*. It is a fine rich ore of the kind, very free from any heterogeneous matter of a pernicious quality; but it is at present very much mixed with a fine white and pure spar, which easily separates from the ore in the ordinary methods of washing, and what remains in the cleaned or dressed ore is found to serve as a flux, and rather to promote than to retard the smelting of the ore.

When I was at Strontian a few years ago, they had some ore in several veins, part of which they worked occasionally; and they had generally about three or four feet of pretty good ore in the soles of the works in the principal vein, flowered and mixed with a pure and friable spar.

Another famous vein of this species was worked at Llangunog in Wales, in the Duke of Powis's time, whose property it was. Llangunog was perhaps the richest vein of lead ore, for the time it lasted, of any yet discovered in this island. For a considerable time, there was a solid rib of clean ore, five yards wide, in the middle of the vein, which was poured out of the kebbles at the shaft head into the waggons, and carried directly to the smelting house, without being touched by the washers and dressers of ore; and besides, there were several feet upon the sides of the vein, mixed with spar and other stony matter, which went through the hands of the washers.

This rich and noble vein was at once cut off below by a bed of black schistus or shiver, and that so entirely, that there was not the least fissure or vestige of the vein remaining, or ever could be found afterwards, though diligent search was made by the most skilful miners for several years.

Now, I reckon it material for the intelligent mine-master to know the distinguishable difference between the gash and the slip vein, to enable him to manage properly in the case of such accidents. When the slip vein is in a twitch, whether it be horizontal or perpendicular, the vein opens again by sinking down or driving forward through that twitch; but at Llangunog the vein never opened, and no trace of it could ever be found, though di-

ligently sought at a very great expence; and no wonder, for in fact it was not to be found. The crack or gash which broke asunder the harder rock above, did not enter into the bed of shiver below, and, of consequence, there was no vein or fissure in the schistus in that place. Strontian and Llangunog are eminent instances of the distinction I made above between the gash and the slip veins.

From what has been said of the gash, it appears, that this species of mineral vein is easily described, it being an open fissure in the rock, generally running in a straight line, often nearly perpendicular, as that at Strontian, and always wider above than below, at a considerable depth.

The other species of rake vein, which I call the *slip*, is not so easily described, the variety of this species being very great, and all of them subject to great diversity of accidents. I shall, however, endeavour to describe some of the great variety of the rake veins, or perpendicular mineral fissures, beginning first with the most regular, and I think I may say the most profitable of all mineral veins.

The vein which I call the most regular, is one that runs in a straight line to a considerable distance upon the bearing, sets downwards near the perpendicular, at least to a considerable depth, with an equal hade or slope, has room enough between the sides, which we will suppose should be

at least between three and four feet, or good drift room, and a good regular vein continues so open betwixt the hanger and ledger for a great way forward as we advance upon the line of bearing in it, and for a great depth as we work down in it; or, in other words, the regular vein is equally wide betwixt sides to a considerable distance forward upon the bearing, and downwards. Some of these regular veins are quick, and others dead, as they are called by miners. A quick vein, or a bearing vein, is one that carries ore, and a dead vein is one that only carries some kind of mineral soil, but no ore. Some of these regular rake veins bear a solid rib of ore, of one, two, or three feet wide, for a considerable stretch forwards and downwards, and some of them bear two, three, or more thin ribs of ore, of various dimensions, from half an inch to five or six inches thick, with spar or other mineral matter interposed between them.

One of the most regular and most durable of these was a rib of steel-grained lead ore at Darenfawr in Cardiganshire. There I saw between twenty and thirty miners in a row, one before another, stoping upon the low soles, about fifty fathoms below the surface, besides as many, or more, who were sumping, driving, and roofing in other parts of the work upon the same vein, and a great many more were at the same time working upon a string which struck off with an acute angle from the principal vein; and, as the soles of the string

were nearly upon a level with the soles of the vein, I could see the miners who were stoping out the ore in the string, by turning an acute-angled corner where the string came into the vein. This fine rib of ore was generally about three feet wide, both in the vein and string; but in some places it was reduced to two feet, and in others it swelled out to near four feet wide.

There are in many parts of Britain, &c. a great many regular veins which carry no ore at all where they are tried, and others carry a small rib, or ribs, but so insignificant as not to be worth working, though the ore gave five times the price; and again, others produce small detached bits here and there as we advance in them not worth working.

It is a very common thing to see dead veins, that is, such as bear no ore at all, continue very promising and regular for a great way, both in driving and sinking in them. I have seen more than fifty fathoms driven in some of these regular veins under great cover, that is, under perhaps twenty or more fathoms below the surface, where the mineral veins were promising, and what we reckon likely to produce ore, and yet no ore was found, or none to signify; only so much perhaps as to show the miners what sort of ore they were to expect, and to tempt them to go on, when, nevertheless, the veins continued perfectly regular, and the sides about four or five feet asunder all

the way. I will speak hereafter of the mineral soils, hard and soft, which fill up the space between the sides of the dead veins.

There are again many regular veins which are not so wide and roomy between the sides as those I have described above.

Some of these regular thin or close veins contain ore at the superficies of the strata, and others contain none at the surface. What they may carry farther down cannot be known without proper trials, and it is but seldom that proper trials are made in them, even although they carry some ore at the surface where they are discovered, their confined appearance being a great discouragement to extensive trials. I know very well that there is a general aversion, both among skilful miners and others, to the trying of these narrow veins, even when they carry some ore at the surface. I have seen a great number of superficial trials in such as carried some ore, but do not remember ever seeing a thorough trial made in any one of them. A little hole, five or six feet down, or a longitudinal opening along the vein, perhaps not so deep, generally ends the trial. How far this may be right, I will not positively determine; however, it may be proper for me to give my own observations upon a point of so much importance to the public, as these veins are very common in all countries where the superficies of the strata is seen; and, in general, I have observed that the greatest num-

ber of such veins as are roomy and capacious between the sides at a good depth, that is, from ten to twenty fathoms down, are generally very strait and close at the superficies of the strata; and besides such as I have seen in mining fields, I have examined great numbers of them in deep glens or gulphs, cut or scooped by rivulets in mountainous places, and upon the shores of the ocean in many parts of Britain, particularly round Caithness and other parts of the north of Scotland, and several arms or inlets of the sea in the Highlands of Scotland, and part of Galloway, in all of which places the rocky cliffs are generally very high and clean, washed by the dashing of the waves. It is astonishing what a number of fine mineral veins are to be seen in many places upon those coasts, many of them containing some ore and other good mineral symptoms. At present, let it suffice to observe, that the most of the veins which I have seen cut deep down by the water or otherwise, are narrow or close at the surface, and wider below: At the same time, it is also proper to observe, that it is very uncertain at what depth they begin to open. A great number of fine veins, with their sides perfectly close above, appearing at the superficies of the strata no wider than a common joint, the sides of the vein perhaps not an inch asunder, nevertheless, gradually open downwards, until the cavity or body of the vein between the sides, at twenty or thirty fathoms deep, is six

or eight feet wide, or more; some, which are close above and wide below, begin to open at two or three fathoms below the surface; others do not open until they are eight or ten fathoms down: and again, some continue so close and strait for a great way down, that they are not a foot wide at twenty fathoms below the surface, which, nevertheless, open out to several feet wide at a greater depth.

These remarks seem to favour strait or narrow veins, and, in my extensive observations, I do not remember seeing many such as were close or narrow at the surface, which did not open below, if there was an opportunity of seeing them at a good depth.

There may be several reasons given for this species of vein being narrow above and wide below; but these reasons will become obvious to the observing miner and the intelligent naturalist, when they come to read and consider the natural history of the phenomena of the strata in general.

CHAP. II.

OF THE MINERAL SUBSTANCES WITH WHICH VEINS ARE FILLED.

One of the greatest points of difficulty in describing wide veins, is to convey a proper idea of the various mineral substances, hard and soft, and of the various conditions of the ores found in such veins; for it would be a very easy matter to say that a vein is so many feet or yards wide: But the various phenomena of the inside of these veins, and of the soils or mineral matters they contain, is not easily described or conceived, without seeing them in their various appearances.

I observed before, that the two sides of a mineral vein are called by miners the *hanger* and *ledger*. These sides are always of the rock or strata which compose the mountain or mining field, the vein being a crack or fissure in those strata. What are called dead veins, that is, those which do not bear ore at the surface, or produce any upon such trials as may be made in them, frequently contain between their sides, in different places, a vast variety of mineral stones and soft mineral soils. The most common and the most promising of the

mineral stones, as concomitants of ore, are the spars and vein-stones of different species. What I call vein-stone, is a compound mineral concretion, of various colours, appearances, and degrees of hardness, and not unfrequently of various colours in the same mass. This compounded stony concretion is called by miners a *rider*, perhaps from its riding the vein, or separating it longitudinally into two or more divisions. This mineral stone is sometimes hard and heavy, sometimes compact and solid, but frequently cracked and cavernous, and rising in irregular and misshapen masses. A rider frequently contains a variety of different substances in the same mass, such as spar, quartz, fragments of the rocks near the vein, sometimes pyrites, and often ore in grains and flowers, and sometimes different ores, as lead, copper, &c. in the same mass, and all these firmly concreted together by a whitish or a brownish white substance, resembling quartz and agate, which seems to have enveloped the several matters in the composition when the whole was in a fluid state. I call this *vein-stone*, as I think the term should be the most intelligible to naturalists, it being always found in veins, in fragments, and masses upon the superficies of them. But the vein-stone does not always contain so great a variety in its composition. It is often pretty white, and appears like a quartzy concretion of a porous, or rather a cavernous texture; and the inside of the caverns, though small,

frequently contain a brownish ferruginous * soft soil, of a snuffy appearance; and sometimes the inside of these small caverns is finely lined with great numbers of crystals, generally exceeding beautiful. In many places these vein-stones are of a brown or a reddish brown, and other colours; but the whitish colour most commonly prevails. This vein-stone is found in all degrees of thickness, from a few inches up to several feet; and strong bold veins carry such a rib or body of it as to appear in a ridge above the surface of the ground a great way, the superficies of the native rock being withered and wasted away from both sides of it.

The next most common stone found in mineral veins is spar, of which there are several species, and these are frequently tinged with several colours, especially in veins which contain less or more of copper or iron. There are three different species of mineral spars, viz. 1*st*, the *calcareous spar*; 2*d*, *cauk spar*; and, 3*d*, the *quartzy spar*.

1. The calcareous spar found in lead mines is commonly, though not always, of a white and whitish colour, both the homogeneous and that which is mixed with ore and other mineral matter, unless it happen to be tinged with soft soils, in which it

* This soft soil which the Author considers as ferruginous, is more frequently the brown oxide of manganese.—EDITOR.

is often found: I say it is commonly white, or of a bluish, a yellowish, a reddish, or a brownish white colour, frequently of a loose friable constitution, and generally of the same internal grain and texture as the ore with which it is accompanied in the vein. Some of this spar is of a scaly and of a tabular texture; some of it again is of a granulated texture, which appears uniform internally, and much of it is of a cubical or diced structure; some of larger, and others of smaller cubes, slightly adhering to one another.

2. Cauk spar is different from calcareous, and it is not generally of so pure a white as the calcareous spars. I have seen cauk spar of a dead white; but most commonly it is of a yellowish, a brownish, or a reddish white, or of a flesh colour: It is a dull ill-looking spar, frequently rising in glebes and irregular masses, and so exceedingly heavy, that miners have often imagined that it contained metal; only they think that the proper flux for it is not yet discovered. No doubt this mineral body is replete with the vitriolic acid and other mineral matter, which the art of the chemist may extract: at the same time, I think it highly probable that it is not a metallic ore. This spar being so very ponderous, makes it very difficult to separate it from the metallic ores in dressing them *.

* The cauk spar described in the text is known in chemistry and mineralogy by the names of *sulphate of barytes, terra ponde-*

3. Quartzy spar is generally of as pure a white colour as the calcareous, frequently more beautiful, and sometimes not unlike it in appearance; but it is of quite a different quality, as it will not effervesce with aquafortis, or burn into lime, which are properties of the calcareous spar: On the contrary, instead of calcining, it is converted into glass or slag in the fire. Some of this species of spar is found of a cubical and of a tabulated texture, resembling the structure of the common blue potter's ore; and I have seen much of it fine, smooth, and uniform throughout, without any visible grain or texture, and it is apt to shoot into prismatical crystals, which are commonly found pure and pellucid, and generally so hard as to cut glass.

Most of the mineral spars are found in prismatical, cubic, or other regular figures. These figured crystals are generally transparent and very beautiful. It is a great curiosity to behold the inside of some of the large cavities in which they are formed. These open caverns are frequently met with in hard mineral veins, and they are generally called by miners *lochs* or *loch-holes*. The magnitude of these caverns is generally in some proportion to the capacity of the veins in which they are found, and the insides of them frequently

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rosa, and *heavy spar*. Its constituent parts, when pure, are sulphuric acid and barytes. The latter is one of the earths, the discovery of which is owing to modern chemistry.—EDITOR.

exhibit all the variety, beauty, and splendour of the most curious grotto work.

There is commonly a hard concreted stony crust, which adheres to the inside of the cavity, and out of which, as out of a root, an innumerable multitude of short prismatical crystals are shot, which sparkle like a thousand diamonds with the light of a candle, or when brought up to the sun. Between these clusters of mock diamonds, and sticking to them promiscuously, there are often ore, pyrites, and spar, shot also into prismatical, cubic, and other figures; and besides these clusters of grotesque figures, which grow out of, and are as it were piled upon each other, the whole inside of the cavern is sometimes magnificently adorned with the most grotesque figures, growing upon, and branching out of one another. But it may be remarked, that these caverns are most beautiful when there is some yellow copper ore or pyrites in them, as these ores are found to produce in hard veins the finest colours. An eminent instance in proof of this assertion is to be seen in the copper veins in the parish of Colvend in Galloway.

Neither the calcareous nor the cauk spars will strike fire with steel, unless there is a mixture of the pyrites in them; but the quartzy spar, on the contrary, gives fire plentifully. Pure quartz of a fine, smooth, uniform texture, breaking like glass, is often found in those mines where the quartzy

spar prevails, and it is frequently mixed with ore. This pure quartz is a white, semi-transparent, hard and heavy stone, of a fine, smooth, uniform texture, of considerable brightness, and not exhibiting any visible grain. It does not rise in blocks or regular masses, either in the mines or any where else, being full of cracks and flaws, so as to break into small irregular masses, with various sharp angles, and it is so hard as to waste the tools more than any other stone. Where quartz and quartzy spar prevail, the veins are commonly very hard and difficult to work, and it is as difficult to separate the ore from the quartz in dressing it, being so hard that it requires much labour to break the quartz mixed with ore small enough, and so heavy, that it does not easily separate. I will only give this specimen of such mineral stones as are most common and most generally known; there are a great many others found in different mines of various colours and textures too tedious to be described.

The soft mineral soils are as various in quality and appearance as the hard. I will point out a few of them. The *first* I will take notice of is a white or whitish mineral soil or clay, sometimes fine, tenacious, and smooth, but often more friable and coarse to the touch, not unlike slaked lime mixed with small sand. This species of mineral soil is frequently a promising symptom of lead

ore; but I will leave the discussion of this point until I come to examine the symptoms and appearances of mines or good mineral veins.

2*d*, Red fatty clay in veins, which indelibly stains the hands and cloaths, is an indication of iron, concerning which I will say nothing just now, but that the better sorts of iron ores are generally accompanied with red staining softness, by which they are easily distinguished; at the same time it is proper to observe, that some lead and copper veins contain a considerable quantity of iron, and consequently of a red, or a brownish red soft soil, and especially near the surface.

3*d*, Bluish and greenish mineral soils, light and friable, and also heavy and tenacious. These, and several others, will be treated of when we come to examine symptoms.

4*th*, Yellowish, ash-coloured, and marbled soft soils, or mineral clays, which are frequently not to be distinguished from surface clays of the same colours, but by the skilful miner.

5*th*, Black and blackish brown soft soils, commonly light and friable, though there are some of them more tough and weighty.

6*th*, The most remarkable and distinguished of all the soft mineral soils, and frequently the most promising, is of a brown colour, and of a lax and friable texture, often resembling rapee and other snuff in colour and appearance; and being some-

times blackish, but generally brown, in all the degrees and shades of that colour *.

HAVING given this brief specimen of the hard and soft soils which are most commonly found in mineral veins, I will now return to the history of the veins, and of the appearance these soils make in them.

It is very common to find a large body of rider, in such a strong vein as the last mentioned, in a rib, or standing in the middle of the vein like a wall, with a space between it and the sides of the vein. This rib of rider or vein-stone so situated divides the vein in two, as there is a space like a vein betwixt this rib and each of the real sides of the vein.

This rib or body of vein-stone is of various dimensions, from five or six inches up to five or six feet thick. In strong veins, like the one presently under consideration, it is not uncommon to find a body of vein-stone several feet thick. Sometimes this vein-stone is richly flowered, spotted, and veined with ore, and sometimes there is little or no ore found in it; and it frequently happens that when it is mixed with some ore, it is found in such small specks and threads, and the stone is so hard, that it is not worth separating. This rib of

* This is the oxide of manganese already mentioned.—EDITOR.

rider in a strong vein is not always exactly in the middle of the vein, but is frequently found nearer to one side than the other, and it is not uncommon to find it adhering strongly to the side, and mixed with ore. When a rib or wall of rider is situated in the middle of a wide vein, there is sometimes good ore found upon each side of it, and at other times upon one side only; and this ore is found either in a continued rib or discontinuous masses.

When the ore is found in ribs betwixt the veinstone and the real sides, these ribs of ore, as well as that of the stone, are of various dimensions, from two or three inches up to two or three feet or more in thickness. In strong wide veins, which have a rib of rider in the middle, it is not uncommon to have a rib of good ore upon each side of the rider, of one, two, or three feet thick, though it is not commonly found so thick upon each side; but it is common to have a rib of two or three feet thick, or more, upon one side of the veinstone, and a thin rib upon the other.

These continued regular ribs of ore, which are found in wide veins, running parallel to the rib of rider, and betwixt it and the sides of the vein, are sometimes solid ore, and sometimes mixed with spar and other heterogeneous matter; and it often happens that ore, found thus betwixt a rider and the side or sides of the vein, is partly solid and partly mixed.

Again, the ore found betwixt a rider and the sides of a vein, is not always in regular continued ribs. It is sometimes found in a discontinuous rib or ribs, that is, in large flat slabs or masses, which appear like a rib for two or three feet, perhaps for five or six, every way, and then you come to the end of it, if you are working forward horizontally, or to the bottom of the mass, if you are sinking down in the vein; but then you are not long before you touch the edge of another cake of this discontinued rib. These cakes, or flat masses of ore in the discontinued rib, are of various sizes, and the distance betwixt them is as various as the dimensions of the masses. In different veins, and in different parts of the same vein, the masses are so near one another as sometimes almost to touch, and at other times there is a distance of from a foot to five or six feet between the masses, and frequently more; but this distance is exceedingly variable, even in the same vein, and often it is very short.

It is proper to observe here, that these discontinuous ribs of ore are imbedded in one of the soft mineral soils mentioned above; that is to say, all the masses or slabs of ore are encompassed with soft soil, and the same softness continues betwixt mass and mass; and it is further to be observed, that although the rib is really discontinued, and that there is less or more space betwixt the different masses of ore, yet they are thinner and thinner to-

wards the edge of the mass, and do not break off at once when at full thickness. The discontinuous, as well as the continued and regular ribs of ore, are of various dimensions or thickness, from an inch up to two or three feet or more.

A discontinuous rib of ore is often found every way as described above, in a vein, without any rib or continued body of rider. Again, the ore is frequently found betwixt the rider and the sides of large roomy veins, in glebes and irregular masses of various sizes and dimensions, imbedded in, and surrounded with soft matters. Some of these roundish masses are no bigger than eggs; others are so large as to produce several tons of ore out of the same mass.

Rider in a vein is not always found in a continued rib. It is frequently found discontinuous; sometimes in a vein that is more hard and close; but generally amongst soft matters in a vein that is loose and open; and moreover, rider is not only found in ribs of several dimensions, and in several degrees of continuity, but it is also found in larger and smaller glebes and irregular masses. These glebes and irregular masses of rider or veinstone in wide, soft, loose veins, are found of all dimensions, from the size of the fist up to the size of a hogshead, and much bigger. In some very wide loose veins, irregular masses of rider will be found in one side of the vein, and irregular masses of ore in the other, and both the masses of rider,

and those of the ore, lying without any order among soft loose mineral soil, and without the least appearance of continuity: Sometimes the masses being pretty near and contiguous to one another, and sometimes the miners have to work forward or downward several feet of the soft soil before they touch one of them.

These large masses of rider are frequently so very hard, even among the loose soil which surrounds them, that they cannot be broken to pieces without gun-powder; and such masses of vein-stone, found loose and detached, are of all colours, as white, yellow, red, brown, black, &c. in all shades and varieties, and frequently several of these colours are blended together in the same mass. These masses of rider lodged in soft soil in wide loose veins, are sometimes poor, sometimes rich in ore, but they are frequently found to contain none at all. When they are poor in metal, they are then to be called riders mixed with ore; but when they are very rich in metal, they may be called masses of ore mixed with rider. It is not uncommon to find these riders mixed with several species of ore in the same mass, as, for instance, lead, copper, iron, pyrites, &c. which mixture generally renders them all very useless, the riders being often so hard that it is not easy to break them small enough for separation, and the different ores so mixed and combined together, that clean ore can hardly be made out of any one of them.

Again, wide, soft, loose veins sometimes only produce larger and smaller masses of ore without any rider at all. The size of these glebes and masses of ore in soft wide veins is various. It is common to find detached bits amongst the soft soils as small as peas, and even smaller, but generally so coated over as to be imperceptible, until they happen to be crushed or bruised between two hard bodies, when their bright metallic quality appears. Some of these detached pieces are large unwieldy masses, which cannot be stirred from the place where they are found, but must be wrought out piece-meal; and in some very wide soft veins, they sometimes meet with masses so large as to produce a great many tons of lead out of one lump.

These larger and smaller lumps of ore in some soft works are all pure and solid; in others, they are less or more mixed and blended with spar, rider, stone, and other heterogeneous bodies. In some soft veins, pure and mixed masses of different species of ore are found, such as lead, copper, iron, &c.; and there are often found masses of all sizes of different kinds of stone, besides spar and rider; and every substance found in the inside of these soft loose veins generally has the appearance of being corroded and wasted, the masses, large and small, of ore, and others, being of no determined or regular shape, but having much the appearance of some degree of corrosion, and a par-

tial wasting as they harden, the soft soils generally having a lax texture and appearance, like slaked lime or snuff. I hinted before that the lax dusty soils are of various colours, though a snuffy colour or darker brown is the most common. These soft lax soils are called *mother* by Scots miners, and where discovered in a vein, they are generally reckoned a good omen both of lead and copper. Some soft loose veins, nevertheless, contain a great quantity of these soft soils without any ore, so far as they are tried; and there are often considerable trials made in it, the soil being reckoned so fruitful of ore, and so often to accompany it, which often proves a temptation to go on.

I will now proceed to observe, that all bold wide veins are not soft. Many of them are very hard; and are various in their appearances and in their contents. Some of these bold veins have produced great bodies of lead ore. At Llangunog in Wales, they had fifteen feet wide of ore, besides several feet more mixed with spar, rider, &c.; and from the reports of tradition, which are corroborated by circumstances, it appears they had ore of great width at Strontian, in the Highlands of Scotland, in the York Building Company's time, and ore of great width has been wrought in hard veins in several other parts of Britain. They had solid lead ore of six feet wide at Wanlockhead in Scotland when Mr Telfer had those works. I saw it afterwards four feet wide of fine solid ore in the same

vein. They have frequently had remarkably rich lead ore in several veins at Leadhills; and it is said to be up to fourteen feet wide of solid ore at present in one of those veins *; and four, five, or six feet of solid ore in hard veins, and sometimes much more, have been no uncommon occurrences in several parts of England and Wales.

Wide hard veins frequently carry a strong body of hard rider of several feet, and sometimes of several yards thick. In some places a rib of ore is found upon one side of this rider, and in others upon both sides of it; and it is but too common that none at all is found, either upon the one side or the other.

Hard bold veins, containing no metal to begin with, are very discouraging for mineral trials, the ground being so very difficult to cut, that trials in them soon become very expensive; but sometimes this difficulty is in part removed by a thin streak or seam of clay betwixt the rider and the side or sides of the vein, which miners call a *steeking*, and which helps them forward greatly, as they cut this out first the length of a pick handle, which frees the *hards*, and makes it easier wrought with gunpowder or otherwise.

It is almost as difficult to describe the inside of

* This was in the Susannah vein, at a place where a string passed off, in which case the vein is usually thicker.—Editor.

a hard vein as a soft one, as the riders, spars, and ores appear in such a variety of conditions and mixtures in different veins.

I observed above that some hard veins carry a rib or body of rider, with a rib of ore upon one or both sides of the rider. These ribs of ore are of various dimensions or thickness, from less than one inch up to three, four, or five feet; sometimes these ribs of ore, running parallel to a rider in hard wide veins, are fine and solid, but they are more frequently found mixed and debased with spar and other heterogeneous matter. It is not uncommon to find the ore in one of these hard veins so mixed and blended with a prodigious body of strong rider of great width, as to render it very difficult to work; and, therefore, the ore must be in considerable quantity, when so mixed, to defray the expences of raising and dressing it.

Again, some wide hard veins have little or no rider in them, but contain a considerable body of ore mixed with spar of several feet thick. Some of these wide veins of ore mixed with spar are pretty rich in ore, so as to be worth working with profit; others, though wide, are hardly worth working, and many of them are so poor in ore as to be worth nothing at all; and there are some wide bold veins which contain a great body of spar, as there are others of rider without any ore at all.

And again, there are some bold regular good like veins, containing a considerable quantity of ore, which is all spoiled and rendered useless by its being blended with a great body of cauk spar, from which it cannot be separated with moderate expence; and some good veins of ore are spoiled and rendered useless by being mixed with a great quantity of pyrites, or mundic, as it is called by Cornish miners. There is sometimes a rib of three or four feet or more of the pyrites found in a wide vein, with a considerable quantity of fine lead ore. If the lead ore happen luckily to lie in a rib, or otherwise, in one side of the vein, it may be wrought with profit; but if the metal and pyrites are blended together, it is ten to one that the lead is not worth working; the mundic or pyrites being so ponderous that it cannot easily be separated.

Wide sparry veins sometimes carry two or three or more ribs of ore, separated from one another by so many ribs of spar, which are not always worth working; for it too often happens that when ore is in this or in any other way divided, it is rendered unprofitable: this, however, depends upon the quality and goodness of the ore. If the ribs are each of them some inches thick of pure solid ore, they may work very well; but sometimes such divided ribs are not above one inch each, and even less.

I have dwelt long upon what may be called re-

gular veins, and yet I have not finished their history; a great deal more may be said about them. but that I may not be unprofitably tedious, I will remark here in general, that every word I have said about wide veins, hard and soft, might be repeated in giving the history of those which are in all degrees narrower. The ore, the spars and riders, and all the soft soils with and without ore, appear exactly in the same manner in the middling and lesser veins as in the large and wide ones, only allowing for quantity. There is not so much room in the lesser ones as in the greater; but they contain the same matters, and they are compounded and disposed alike in each; and therefore I will refer to what I have said about the large and wide veins, to serve for the history of the middle and small veins.

CHAP. III.

OF IRREGULAR RAKE VEINS.

HAVING in the former Chapter treated of terials with which veins are filled, and of t ner in which these materials are distributed will enable us more distinctly to unders nature of mineral veins, I will now pro give some account of such rake veins as called irregular; and these are, 1*st*, Such suddenly into very wide bellies, and close again as suddenly: 2*d*, Waving veins, or open and close alternately at very short d in working forward horizontally in ther 3*d*, Such rake veins as have a very great slope, which is a sufficient irregularity c and besides these, are apt to be very irreg width. These three are only varieties of t vein; and, indeed, the varieties are so nu that it would be difficult to describe them

1. Some hard veins come under the des of these three; and it is not uncommon t pretty wide and rich belly of good solid ore does not continue for any considerable len proceeding forward upon the bearing of t

but soon checks or twitches out by the sides of the vein coming together. By *soon twitches out*, I mean that it fails at the end of a few fathoms, where the sides of the vein come together, either suddenly, or more gradually; the twitch being either total or partial. Some of these twitches carry a small rib of solid ore quite through, until the vein opens again, and produces another belly; in other twitches, we have a rib of rider going quite through, the rider being sometimes mixed with ore, and at other times quite barren: and, again, in many of these twitches we have neither ore nor rider, but in some of them the sides of the vein are squeezed as close together as a joint between two hewn stones, and in others there is nothing but a thin streak or seam of clay, perhaps not an inch thick. Miners call this thin seam of clay a *sticking*. When there is either a thread or small rib of ore, pure or mixed with spar or rider, or else a rib of barren rider leading through the twitch, or again, where there is a sticking of clay, there is no difficulty in the case, except in point of labour and expence. An inexperienced miner may find his way through the twitch well enough; but where the sides come perfectly close, and are run or cemented together, which is often the case, it then requires the care and attention of an experienced miner to keep the vein with certainty as he drives through the twitch, especially if it prove a long one.

In general, veins do not close at once when one of these twitches is coming in, but the belly of ore begins from the widest part to wear gradually less and less, until at last the sides of the vein are pretty close together, and the ore wears out to a point or thin edge, or is entirely interrupted. These twitches are of various lengths.

No miner, when his vein is checked or twitched out, can possibly tell how long it is to continue twitched, or, in other words, how many fathoms he has to drive through it before the vein opens again; and this uncertainty of the length or extent of twitches is one of the greatest difficulties in the practice of mining. Some of these bars betwixt bellies or wide places in a vein do not continue above two or three fathoms before the vein begins to open again upon the other side; but others continue for ten, twenty, thirty, or forty fathoms, or even a hundred fathoms; so that we are frequently in a sad dilemma, when we have driven ten or fifteen fathoms in an unknown twitch, and it is very hard to determine whether we should push forward or stop short. When the miners have cut a drift through a twitch, the vein begins to open, and the sides to part asunder upon the other side. If they had a thin rib of ore to lead them through the twitch, it begins to grow thicker; but if they had none, they first touch the thin edge of it. Perhaps they first touch it at an inch thick, or even less; but as they advance forward,

the ore increases gradually, and grows better and better, until they come to the best and widest part of the belly.

These bellies of ore are of indeterminate dimensions both as to length and breadth or thickness; some of them are but few fathoms long, others continue for a great many fathoms; some continue at full wideness where the ore is best for several fathoms, and others begin to dwindle or wear thinner almost as soon as you arrive at the best and thickest part of the belly, and again they vary as much in width or thickness as in length, as they are found in different veins, and sometimes in different places in the same vein, from a few inches up to several yards wide. It sometimes happens, that the miners meet with a false appearance in driving through a twitch, that is, with a small quantity of ore, which does not continue, either as they advance, or up and down; but they soon lose it again, which is a great disappointment, as they naturally expect, in such a case, that they have got hold of one edge of a belly of ore, but it proves only a small nest. When one belly of ore proves pure and solid, it generally happens that all the bellies prove so in the same vein, and especially in the contiguous parts of the mining field; but the contents and produce of a vein frequently change greatly at a distance.

I have, as yet, in this vein only mentioned solid bellies of ore; but it must be observed, that where

ore is found in this description of vein, it is not always solid; on the contrary, it is often found mixed with spar and rider; and too often these bellies in this sort of hard vein only contain spar or rider without any ore, or so little that it is not worth working. It is in these veins that the open cavities spoken of above are most frequently met with.

I hinted before, that the miners know nothing about these lochs or cavities until they strike their tool into one of them at once, nor do they know any thing about the dimensions of them until they open them up; for they are, as I hinted, of all dimensions, from the size of an egg to the size of a small house. Miners are well pleased to meet with these cavities in hard veins, especially after driving a long time in a hard check or twitch, as one of these loch-holes proves the first and surest indication of the veins beginning to open again, and of another belly of ore coming in. When this species of hard veins is barren of ore, the spars and riders, &c. are found in them in bellies, in the same way as the ore is found in the bearing veins; and these barren hard soils begin and end in a narrow or thin edge at the extremities, and swell out gradually in the middle of the belly, exactly as the ore does; and the checks or twitches are the same in the barren as in the bearing veins. Sometimes a thin rib of the spar or rider they contain leads through the twitch, and sometimes

a thin sticking of clay, or else the sides of the vein are found squeezed close together, as formerly described.

The soft soils found in the bellies of this sort of vein are much the same as in the soft and wide regular vein; and the ore is found in them much in the same manner, excepting that there are no regular ribs. The ore in these wide and spacious cavities or bellies of soft veins, is generally found in glebes or irregular masses, of a roundish or oval figure, of various dimensions, and surrounded with soft soil.

I observed of the hard veins of this description, that the bellies of ore, or of spar or rider in them, swell out sometimes to several yards wide in the middle of the belly; but some of the cavities or bellies of the soft veins prove a great deal wider. It is no uncommon thing in North Wales, and many other places, to find the soft openings in this sort of vein swell out to an enormous wideness, so as sometimes to make it difficult to find the real sides of the vein, and sometimes the real sides are shaken and loose, occasioned by the softness of the soil within them. Working these soft veins is the most difficult part of mining. There is no advancing a foot in them, without using square timbers to form a safe passage; each pair of which timbers is composed of two door-cheeks or side-posts, and of a lintel and sole-tree. The miners stand within this square timber when they

work, and still set more timber as they make room for it. This is expensive, troublesome, and dangerous, if they have not good skill in setting the timber, for the soil is generally quite soft and loose; and being commonly mixed with masses of ore and stone, the whole frequently rushes down with violence before their timber to a greater height than they incline; but a skilful miner does all he can to prevent the soil from running or rushing down before his timbers, by driving in sharp-pointed stakes. He enters these above the lintel or head-tree, and without the side-posts of his foremost pair, and with his mallet drives them forward beyond the square timbers into the soft substance; and if a mass of ore, or any other hard substance, oppose the point of one of his stakes, he draws it out of the way with his pick; and when the end of the stake is freed, he drives again until it is far enough up; and when the stakes are all driven as far up or forward as is wished, he then works out room to set another pair, and so on; and whether he advances horizontally, sinks down, or rises upwards in these soft places, he must do all with square timbers, which is very troublesome and expensive; but it frequently happens that the ore is so plentiful and good in these veins as abundantly to compensate all this trouble and expence.

These spacious bellies in soft veins frequently contain glebes and masses of ore of various sizes, intermixed with a quantity of soft friable mineral

soil; and sometimes the quantity of soft soil is very great, in proportion to the quantity of ore produced. In these veins large and small glebes of ore are met with, exactly as they are found in the wide and soft regular veins described above, excepting that no regular ribs are found in such irregular bellied veins; and it is not uncommon to find in the soft opening of one of these irregular veins a single mass of ore so large as to take a considerable time to work it out, and to prove a great treasure to the proprietors.

These enormous masses of ore are by some miners called bellies of ore; but, properly speaking, the belly is the sudden dilatation or opening asunder of the sides of the vein to a great width, and when they contract or come together again as suddenly.

The glebes of ore found in the soft bellies of these irregular veins are commonly solid and good, that is to say, pure and unmixed with spar and other heterogeneous matter; and such pure and solid glebes cost but little trouble and expence in dressing and preparing for the furnace, and they generally yield a good produce in smelting. But they are not always so rich; sometimes spar, &c. is mixed with them, which makes it necessary to break the most of them down small in washing and dressing the ore, and then the produce in smelting is diminished.

The glebes and masses of lead ore which are

found immersed among soft soils in the cavities of soft mineral veins, are of various colours and appearances. In many soft works, the glebes of ore are all coated over with a white substance resembling lime; but this coating is a kind of native ceruse or efflorescence, occasioned by corrosion, or beginning decay of the outside of the masses. Bits of lead ore lying a long time above, gather the same sort of coating, which undoubtedly is occasioned by the moist and corrosive quality of the atmosphere; and such bits exposed a long time to the influence of the external air, would, in the course of time, be altogether wasted away.

In some soft works there is great appearance that the masses of ore below ground are also corroded, and part of them wasted away, as some of them are found cavernous, as it were honeycombed, and of very irregular figures, the cavities containing a blackish or a brown ferruginous powder; and the whole of the soft soil in which such masses are immersed, has generally a ferruginous appearance, and is of a lax and friable texture. These seemingly corroded masses of ore are not white like those mentioned above, but are generally of a brown or a blackish brown hue on the outside. Again, in some soft works the masses are outwardly of a dull, tarnished, leaden hue, though inwardly, when broken, of a bright lively blue colour.

The most beautiful masses of lead ore I ever beheld were a few years ago at Leadhills in Scotland. These masses were pretty large, few of them being less than one hundred pounds weight, and many of them much more; and the outside of each was of the brightest and most beautiful yellow colour, and the inside of a bright blue, the common colour of lead ore. Upon nearer inspection, I found this colour to be a rich efflorescence upon most of the masses; it was near an inch deep, of a fibrous, columnar, or striated texture, the columns shooting out regularly from the mass all round, and disposed perpendicularly and parallel to one another. From the appearance of the masses, which were all whole and unbroken, I know they must have been found in soft soil*.

I have seen the masses of ore in some soft works of a red colour. This happens when the clay or soft soil contains some iron; and there are several rich lead veins which hold a quantity of iron, both in a hard and soft state, and sometimes too much, so as to render the lead unprofitable. It is not uncommon to see the masses of lead, when drawn out of soft works, of the same colour as the clay,

* The yellow ore described by the Author is phosphate of lead, which is usually found in the upper part of the veins, in detached masses surrounded with soft soil, and frequently forming a coating to masses of galena or common lead ore.—EDITOR.

or other soft soil, in which they were immersed in the vein; and as the colours of these are various, so must the colours of the masses likewise be.

2. The second sort of irregular rake vein I am to describe is what I call the *waving vein*. This is a rake vein or perpendicular fissure, which opens and closes at very short distances. This vein is very near a-kin to the last described, as it consists of bellies and twitches; but the twitches are so numerous and so near to one another, that there is not room or distance enough between them for any of the bellies in this vein to open out to any considerable width; and consequently this vein is never so rich and valuable as the last mentioned.

As the cavities or bellies in this vein are small and of short continuance, so it generally happens that the twitches between them are also short and of no great continuance; and as the small openings and twitches are so frequent and near to one another, I call this the waving vein, as the small bellies in this vein resemble the hollows between the waves on a pool of water.

I have seen both lead and copper veins of this description, but I have not yet seen any of them produce a great quantity of ore; and as the sides of these veins are so distorted by being so frequently squeezed together by numerous twitches, it generally happens that the masses of ore and other mineral soils assume the same form.

3. The third irregular vein of the rake species is that which has a great hade or hang. It may be proper to observe, that the perpendicular fissures or rake veins have a greater or lesser hade or slope in proportion to the declivity of the strata, as the mineral fissure, or vein, is a transverse section cut at right angles to the lay or bed of the strata; that is to say, when the strata are perfectly flat or horizontal, then the mineral fissures we call rake veins are perpendicular; when the strata decline one or two degrees from the horizontal position, then the vein will have a slope of one or two degrees from the perpendicular. Let us suppose, for example, that the strata cut by a rake vein have a declivity to the south of two degrees from the horizontal line; in that case, the vein which cuts these strata will hade or slope as you sink down in it two degrees from the perpendicular towards the north. If the strata dip suddenly to the south, and the declivity is so steep as to be near the angle of forty-five to the horizon, the hade or slope of the vein shall be upon the angle forty-five to the north, or near it, as these veins generally cut the rocks at right angles to the strata; and therefore whatever be the slope of the strata one way, the hade or slope of the vein is as much from the perpendicular in the opposite direction: But then it is also necessary to observe, that this can only be said of that rake vein which runs parallel to the bearing of the strata. There are north and

south, and east and west rake veins, or what are called so by miners, though they seldom answer exactly to these points. The one of these cuts the rocks in a line parallel to the bearing of the strata, and the other cuts right across the strata; so that these two veins intersect one another at right angles. Now the general bearing of the strata in Great Britain, and in all countries under the same parallels of latitude, is nearly from north-east to south-west; consequently the parallel veins, or those which cut the rocks in a line parallel to the bearing of the strata, must point towards the south-west and north-east, or thereby; and those which cut across the strata, and intersect the parallel veins, must run or point from the north-west towards the south-east, or thereby, where the bearing and declivity of the strata are not warped by any accidental cause, but are fair and regular, according to the general course of the strata in the island.

There are also other rake veins, besides the parallel and rectangular ones, which cut the strata in a diagonal line across the slope or declivity. These I call, for distinction sake, *oblique veins*. Now, where the strata are nearly flat or level with the horizon, all these three veins may stand nearly perpendicular; but where the strata have a great declivity, the parallel and the oblique veins likewise have a great hade or slope the contrary way, though the rectangular vein, or that which cuts

the strata in a right line across the bearing, may be nearly upright, when the others have in course a great hade. The veins I call oblique cut the strata in all directions across the slope; of consequence, they either come into or intersect the parallel of the right-angled veins in all directions. I shall have occasion to examine the course of the oblique vein hereafter; and therefore I will drop that part of the history of it here, and will proceed to give some account of such rake veins as have a great hade or slope.

The right-angled veins, that is, such as cut the strata right across, or in a right line from crop to dip of the strata, are generally more upright, or nearer the perpendicular position, than the parallel and oblique veins. I explained before, that these last mentioned veins are nearly upright only when the strata they cut are near the horizontal position; but when the strata hang considerably towards any point, the parallel and oblique veins have also a considerable hade or slope, nearly in proportion to the declivity of the strata; and it is these two veins that come under the description of such rake veins as have a great hade or slope, and therefore deserve to be called *irregular veins*. These veins are generally very troublesome to work, on account of their great hade, and of the irregularity of the hade, as the slope frequently varies; and besides this frequent variation, which is of itself a sufficient irregularity, the two sides,

or hanger and ledger, are also generally very irregular. The hanger or upper side sometimes rises up into a concavity, quite out of the regular flat course, and sometimes again it falls down to a convexity; and if the rock which forms the side happen to be any way tender, this hanging side becomes very troublesome, expensive, and dangerous in supporting it, even where the vein may be called hard; and if the vein happen to be soft, it is still more difficult to support this hanging side. The ledger, or lower side of this vein, is also irregular, falling into concavities, and rising up to convexities.

The natural hade or slope of these veins makes them abundantly troublesome to work, and these additional irregularities of the sides make them still worse; and one of the greatest difficulties in working them, is in getting the produce out of them.

I HAVE dwelt the longer upon the history of the rake vein or perpendicular fissure, because it is the most common and frequent of all veins, and almost the only one as yet wrought in Scotland. I should now proceed to the history of the pipe vein; but before I begin with it, I shall give a brief account of the strings and other partial veins which branch out from the principal ones, as these properly belong to, and accompany the rake veins.

CHAP. IV.

OF PARTIAL VEINS.

THE partial veins proposed to be described in this Chapter are termed, in the technical language of the miner, *strings*, *bars*, *skews*, and *backs*.

A string, in mining, is a discontinued vein or mineral fissure, which flies off in a right line, but with an acute angle from the principal vein; and when it has stretched in that line to an indeterminate, though no great distance, it then terminates in a point, and is squeezed out to nothing by the two sides coming close together, and having no marks or vestige of a vein; or, in other words, it is really the termination of the crack or fissure. The other end, as hinted already, joins the principal vein, and comes into one side of it in an acute angle, but does not cross it; for if it crossed the vein, and were found upon the other side, it would not be a string, but an oblique or diagonal vein. When a string has really joined a vein, they are afterwards in that line no more two but one; the line of the string, and the string itself, being lost in the vein, and the vein only continues the line

of bearing. These strings fly off from the veins in all directions, though always diagonally; and they are sometimes as rich, and I have seen them for a short time even richer than the vein itself; but they at last squeeze out, and come to nothing at a less or greater distance. The rest of the history and description of a string is the same as that of a rake vein.

There is another species of string which has no relation to, and perhaps is not near any vein at all. This species of string is, properly speaking, an imperfect discontinued vein, which neither puts down to any considerable depth, nor does it stretch forward to any considerable distance upon the line of bearing either way; nevertheless it may, for a short time, look as well, and produce as good ore, and other mineral soils, as a real continuous vein.

The mining field in the island of Islay, upon the west coast of Scotland, is remarkable for a great number of these strings, or imperfect discontinuous mineral fissures; some hundreds of which produced, and now contain, a small quantity of good lead ore, and yet certainly come to nothing at the depth of a few feet, or a very few fathoms, and at no great distance in the line of bearing; and that not by a twitch, and such a coalescence of the sides of the vein as will open again further forward in the line of bearing, which is an accident common to all veins, but by the total inter-

ruption of the crack, where the strata appear as whole as a number of unbroken planks lying one above another.

As I have named the island of Islay, it may gratify the curious, if I give a brief history of the mining field in that island. This mining field is chiefly comprehended, or included, in a patch of lime-stone; I call the lime-stone of Islay a *patch*, because it covers but a small part of the island. The lime-field in Islay is compact, or nearly as broad as long, and is somewhere about ten miles over every way; but perhaps the world does not contain a patch of stone of any kind which exhibits a greater number of mineral veins; and it is remarkable, that they almost all bear some good lead ore quite up to the day.

The lime rock in Islay is mostly bare, excepting tufts of grass, and little spots of arable ground, about half an acre, less or more, here and there *.

* The Author's description of the extent of the lime-stone field of Islay is far from being correct; indeed it is contradictory. For a body of lime-stone of one hundred miles square, by his own account, is surely entitled to a denomination which would convey the idea of greater magnitude than the term *patch*. It is probable that it does not exceed fifty miles square; but still it may be considered as a large body of lime stone, covering one-eighth part of the whole surface of the island. The *spots* of arable ground mentioned by the Author must refer only to the mining field; for in most other parts of the lime-stone field, particularly towards the head of Lochindaal,

The superficies of the lime-rock being so generally seen, has given opportunity for discovering so great a number of mineral veins: Of these, some run north and south, some east and west, crossing and intersecting each other nearly at right angles; and others run in an oblique or diagonal direction, crossing and intersecting the others in all manner of angles. It is worthy of remark, that besides the mineral veins, there are also an innumerable multitude of whin dykes, of all sizes and dimensions, which cross and intersect each other, and which cross and intersect the mineral veins in all manner of directions; so that the whole patch of lime-stone is curiously cut and divided into an innumerable multitude of compartments.

Some of the whin-dykes are not a foot thick, while others are from two, four, or six feet thick, to eight, ten, or twelve feet, and some few a great deal thicker. Many of these dykes or ribs of stone run in a parallel direction, and others cross and intersect each other. Great numbers of these ribs of stone rise up into ridges above the surface of the ground, the lime-stone, and other rocks, be-

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there are some of the most extensive inclosures in the kingdom, in no part of which does the lime rock appear, and whose soil, beside the improvement which it receives from skilful management, probably derives no small degree of fertility from the lime-stone and marl on which it rests, and is thus rendered capable of yielding the most abundant crops of every kind of grain.—EDITOR.

ing weathered and washed away from both sides; the whin being very hard, stands the weather better than the contiguous rocks. The quality of these whin-dykes is generally a species of that hard stone which naturalists call *basalts*; and I may just observe, that they are all mineral veins.

I am very sensible that most miners will startle at this observation, and will not acknowledge that they are mineral veins. I hope, however, to make it evident, that they were originally the same sort of fissure, though filled afterwards in whole or in part with matter foreign from what is called mineral or metallic matter. I said *in whole or in part*; and as a proof of my being right, ore has been found upon one or both sides of these ribs of stone. As an instance of this, in the mines of Islay, a rib of solid lead ore was wrought for some short time about three feet, and for a longer time about two feet wide, running parallel to one of these ribs of stone in the same vein, and quite close to it; and deeper down, in the same vein, there was found a considerable width of soft mineral soil, with some lead ore in it, upon the other side of the same rib of stone. I examined this vein, and investigated the truth of the circumstances, only I did not see the ore at its full width; but the master and the miners assured me of the fact; and, moreover, I saw both ore and mineral soil upon one side of some, and upon both sides of others, at the sur-

face of the ground in other parts of this mining field.

I observed before, that this mining field contains a great number of good north and south veins, beside many good east and west veins, all of which cut and intersect one another nearly at right angles; that there are also many diagonal veins which intersect the others at various angles, besides numerous strings and imperfect veins, many of which branch off from the principal veins, and others are quite detached from them; and it is a true, but surprising fact, that some hundreds of these veins, perfect and imperfect, have been tried, and some lead, less or more, found in them all.

The phenomenon of such prodigious numbers of superficial trials within so small a compass of ground, not above ten miles over, struck me with surprise, and, therefore, I made some enquiry about it; and I was informed, that some time ago a company of Glasgow merchants took a lease of this mining field, and their method of working it was as singular as it was pernicious to the future welfare of the mines. Whether I was told that they had any practical miners there or not, I do not now remember; however that may be, their principal way of procuring ore was by employing and encouraging the peasantry of the island to dig and raise the ore at so much per bing, which is a certain weight or measure; and in consequence

of some ore being seen at the surface in numbers of veins, the country people searched, dug, and rummaged the whole face of the mining field. They laid all the veins open to the day, like a trench or ditch, where they found any ore. In some places they did not go down above two or three feet in the veins and strings, at most not above two or three fathoms, when they generally came to more water than they could throw out; and as they had no pump, windlass, or other apparatus for drawing buckets, they could neither bring out the water nor the produce to a greater depth conveniently than about two or three fathoms.

No doubt this imperfect method of rustic mining would produce a considerable quantity of good ore for the time; however, it had a most pernicious effect upon the mining field for the future, as they went down every where in ore as deep as they could for water; and as they cut up the veins along open to the day, they are now so many wet ditches, which receive all the surface water, which conceals the ore they left in the soles, so that it is not easy getting down to examine it in a long ditch of water. However, several of them have been examined, and very good ore found in some of the veins, and smaller ribs of good solid lead ore, from three to six inches, have been seen in the soles of numbers of these superficial old works.

I laboured very hard about three weeks in the island of Islay, viewing and investigating the mineral appearances, and declare I never saw, nor do I ever again expect to see, so many good and regular veins so near to one another, in many of which good ore has been found and wrought; and there is ore very well worth beginning upon in the soles of the superficial works above described, in a considerable number of very fine promising veins.

There are several rivulets and rills of water in the neighbourhood of the mines, and good situations for reservoirs, which, if properly made use of for water engines, the mines of Islay might become very profitable, extensive, and durable.

But to return from this digression, the next of the smaller branches of the mineral veins which I shall take notice of is a *bar*. This is a short discontinuous vein, which runs between two parallel veins, either right across, or in a diagonal direction, and joins them both together, that is, the one end of the bar comes into one of the veins, and the other end goes into the other vein; but it does not cross either of them; it joins them together like the letter H.

A *skew* is an irregular discontinuous mineral fissure, striking out from the principal vein in an uncertain direction, and which generally lies in a very slanting irregular position. These imperfect

mineral fissures seldom stretch out to any considerable distance from the principal veins.

A *back* is a mineral fissure, which often resembles a segment of a circle. The back breaks off from the hanging side of a vein, strikes out to a less or greater distance, fetches a sweep, and comes back into the same vein again at a distance from where it sets out.

All these inferior branches produce good ore in some mines. Ore is sometimes found in so many shapes and situations accompanying good veins, that it would be too tedious to trace it through all its various appearances, if they could all be recollected; but as I think the inquiry of no farther consequence in this place, I will drop it at present. Some part of it will be resumed when I come to point out some other beds of the metallic ores besides regular mineral veins.

CHAP. V.

OF PIPE VEINS, FLAT VEINS, AND ACCUMULATED VEINS.

THREE kinds of mineral veins yet remain to be described, viz. *pipe veins*, *flat veins*, and *accumulated veins*. These will form the subject of the present Chapter, and will be treated of in their order.

I. *Pipe veins*. A pipe vein resembles in many respects a huge irregular cavern, pushing forward into the body of the earth in a sloping direction, and having various degrees of inclination, from a few degrees from the horizontal position to that of an angle of forty-five. In short, they stand in all positions between the perpendicular and the horizontal. The pipe in general does not cut the strata like the rake vein, but it is an opening between them; so that if the lay or position of the strata be nearly horizontal, so is the bearing of the pipe; but if the declivity of the strata be precipitate, the pipe shoots down headlong almost like a shaft. Some pipes are very wide and high, others are very low and narrow, sometimes not larger than a common mine or drift.

Some pipe veins are hard and others are soft. The hard pipes contain all the variety of mineral matter which is commonly found in hard rake veins. Some of them are found quite full of solid ore, others are full of ore mixed with spar, rider, &c. and some again are full of spar or rider without any ore at all. Large pipe veins full of solid ore are generally exceeding rich. These sometimes open out on the right and left hand to a great many fathoms wide, and it frequently happens that they rise up into the roof and sink down into the sole at the same time; so that the pipe, which perhaps was not before much above a fathom high and two fathoms wide, swells out suddenly into a prodigious belly, which in bearing pipes proves immensely rich; but all the hard pipes are not of such spacious dimensions, nor do they all swell out into such large bellies. I saw them working a pipe in Denbighshire in Wales no wider than a good mining shaft or coal-pit. This pipe was almost round, and it put down in the rock with a slope between the angle forty-five and the perpendicular. It was of a tubular form, about six feet diameter, and quite full of good lead ore.

Soft pipe veins are as frequently met with as the hard; that is, such as contain soft mineral soils within the cavity of the pipe, and they are found in various positions as well as the hard; some putting down with a quick, and others with

an easy slope. The ore is found imbedded and buried among the mineral soils in the soft pipes, much in the same manner as in the wide and bellied soft rake veins.

It should be observed, that pipe veins do not always approach the tubular form. Several of them are much wider than they are high, and these flatter pipes frequently come to be very low between the roof and sole, towards the skirts or extremities of the pipe upon the right and left hand. It ought also to be observed, that all pipe veins do not continue betwixt two distinct beds of stone. Sometimes they burst their way up through the strata, and then they have a much greater slope than the ordinary declivity of the strata where they are found.

In some mining fields two or more pipe veins run parallel, and sometimes very near to one another. When they run parallel, and near to each other, they are then generally flatter than a single one, and approach something near to the figure and description of the streeks or flat veins, which are to come next under consideration; and it sometimes happens, that in particular places the skirts or sides of two parallel pipes approach so near to one another as to come into contact; and in this case, when the ore is wrought out of both, a hole or communication is formed between them. This generally happens only when one of them

flies out wider than ordinary into the side next the other.

The bearing of such pipes as continue between the strata is exactly the same as the declivity of the strata; but, properly speaking, pipes have no horizontal bearing whatever: Their bearing is in a declining or sloping line, and is towards the same point of the compass as the declivity or dip of the strata. The slope of one of these pipe veins is the same as the declivity of the strata in the mining field, and even in that part of the field where they are found; and as the declivity of the strata is extremely various, so the slope of these pipes must be equally various.

With respect to the other species of pipe veins which have burst their way up through the strata, it is more difficult to point out their bearing, as they generally dip down precipitately, and may be said to have no bearing at all, as the one end dips down towards the centre, and the other end points up towards the surface; and such of them as do not stand so near the perpendicular, seldom or never run in any straight line whatever, but wind downwards in a sloping and in an oblique direction.

Some parts of this sort of pipe will sometimes put down for a few fathoms as perpendicular as a coal pit or shaft, and not unlike a clumsy round or oval shaft, both as to figure and size, and then it will turn away to one side or other with less or

more slope: It is uncertain which way it will slope until we see it in working; and these pipes frequently open and contract again as we go down in them, and sometimes they will swell and belly out to an enormous wideness, and, lower down, they will contract again as narrow as ever.

This species of pipe veins is generally more irregular than those which continue between the strata; but they have this advantage, that they are generally nearer the perpendicular position, and therefore it is easier to sink shafts in them; however, they do not all put down so near the perpendicular position; several of them have a great slope: But whether they stand nearly upright, or hang with a greater slope, they are all irregular and winding less or more, and they all contract and dilate greatly in width as we go down in them.

II. *Flat veins.* The next bed of the metallic ore which comes under consideration is the *streek*, or *flat* or *dilated vein.* The flat or dilated vein is a space or opening betwen two strata or beds of stone, the one of which lies above, and the other below this vein, in like manner as the roof and pavement of a stratum of coal are above and below that coal. When the strata between which this vein is found lie nearly parallel to the horizon, the vein is likewise in the same horizontal position; and when the strata vary from the hori-

zontal position, the dilated vein varies likewise with the same degree of declivity; and this of necessary consequence, as this vein does not burst the strata, but always continues between the same beds of stone.

These flat veins lie between the strata in some respects as seams of coal are found; at the same time I must observe, that there is no further resemblance between them, than that they are both found between the strata, and that they have exactly the same horizontal or declining position as the strata of the place where they are found: in these respects they are to be investigated upon the same theory as the strata or seams of coal. These veins are also subject to be interrupted, broken, and thrown up and down by dykes, slips, and other interruptions of the regular stretch or plane position of the strata, in the same manner as in the seams of coal, with this difference only, *viz.* that in working coal these interruptions are generally real troubles, and getting over them is so much pure loss of money and time; whereas, on the contrary, when they are met with in working a flat vein, they often prove a great advantage, as they are, in fact, other mineral veins of different denomination and description: so that as often as these interruptions are met with in the flat vein, it is an adventitious increase of the reality, or, at least, the chance of meeting with more treasure in the same field. In other respects, the theory of

lations of *the vein* and *the streek*. By the
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which stretches or spreads in a horizon-
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l position; numbers of them are in a de-
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they must of necessity have the same
as the strata, which are found in all de-
ween the vertical and the horizontal po-

of these veins are met with in argillace-
a of the mountain rocks, in which the
lf is frequently nothing else but a soft ar-
s stratum, often containing masses of py-
r, quartz, and other stones, which, upon
, are found to hold a less or greater quan-
ead ore; and sometimes these softish ar-
s veins contain masses of good solid ore.
standing, I believe these argillaceous strata
dom hold so much ore as to be worth
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are not cracks, fissures, or gashes in the strata like the rake veins, but, on the contrary, they are always found between the strata, and are themselves imperfect strata, or at least each of them occupies the place of a stratum, so that there is a very wide difference in the theory of these two species of veins, the rake vein being always a longitudinal fissure, or break, across the strata in some line of direction; in which case the vein is the chasm or space between the sides of that longitudinal fracture; whereas, on the contrary, the streek or flat vein in this case is a space between two layers of stone, which space is generally filled with some mineral matter or other. But notwithstanding this difference in the natural history of these two species of veins, they have frequently a very striking agreement in their internal contents, appearance, and accidents. The flat or strata veins open and close as well as the rake veins. Sometimes the stratum, which is the immediate roof or lid of this vein, comes down and joins close to that below it, so that there is perhaps no space left between them, and little or no vestige of a vein left; and these twitches, or coming together of the roof and sole of the vein, will continue to a less or greater distance, and the vein be entirely, or in part, squeezed out from betwixt the two layers of stone, as is found in the rake veins, when they check, or their sides close together. Sometimes the strata veins will continue of a moderate and pretty regular

height between the roof and sole for a considerable extent, and at other times the roof and sole come together, and open again at short distances. Sometimes the space, which we may call the cavity of the vein, is but low betwixt the roof and sole; so that when the ore is worth working, part of the roof or rock above it must be worked away with the ore, to give the workmen room to advance; and at other times they open wider or higher, so as to give room for a good body of ore; and, again, they sometimes open up to an enormous height, which may be called the bellies of these veins.

The streek or dilated veins are found both hard and soft: Some of the hard streeks contain a good body of solid ore, others produce ore mixed with spar or vein-stone; and some of them again are found to hold nothing but spar and vein-stone, without any ore at all. Lesser and greater bellies, with loch-holes, or open cavities, with other accidents and alterations, are found in these veins, which in many respects resemble the rake veins.

In soft streeks the ore is sometimes found in large bellies, but more frequently in flattish glebes or irregular cakes, generally lying nearer the sole than the roof. Sometimes several layers of these cakes are found one above another, quite up to the roof of a white vein, with soft mineral soil filling up the spaces between the several masses.

It should be observed here, that when two or

more checks or twitches in a streek or flat vein run in a parallel, and are at no great distance from one another, the streek has then a near affinity to one sort of the pipe vein; and when the parallel twitches are near one another, and the cavities of the veins rise to a considerable height between the twitches, they go then under the denomination of pipes, and are worked as such.

I observed above, that the species of pipe which approaches in affinity to the streek, lies between the strata, and consequently it has the same declivity as the strata, as well as the streek; and when twitches run parallel in one of these streeks, and the roof rises up to a considerable cavity between the twitches, the name *pipe* is then given by the miners.

III. *Accumulated veins.* The last capital vein which I am to take notice of, is the *accumulated vein.* The accumulated, or conical vein, is not easily described, so as to convey a distinct idea of it. Some of these veins approach to the form of vast irregular cones, and others have some resemblance to inverted cones; but whatever be the form or description of this mineral repository, it generally contains a great deal of wealth in a small compass of ground, the accumulated veins being often the richest of all mines.

Some of these veins resemble many of the pipes, especially in their dipping down from the surface,

either in a perpendicular or a slanting direction, and in their being encompassed and circumscribed on all sides with rock; but they frequently differ from the pipes in the interior structure.

The accumulated vein is often pretty narrow, or of small diameter, above, and very wide at a considerable depth down from the surface, and some of them open out to an enormous width in going downwards. But the most remarkable distinction between the accumulated and the pipe vein, is the radiated form of the former, from which a number of lesser veins or mineral fissures diverge every way, and stretch to various distances from the main pipe or body of the vein, in which one end of each terminates.

The main pipe or shaft of the accumulated vein resembles the inside of a glass-house, and the vast capacity of this vein is often stored with a rich body of metallic ore, frequently imbedded in soft mineral soil; but the veins and branches which join this pipe, and diverge from it, commonly resemble rake veins or perpendicular mineral fissures. When the ore is worked out of a large accumulated vein, it exhibits a frightful gulph, some parts of which may be fifty or sixty feet wide below; and it is often worked down to a great depth from the surface.

From some of these large pipes, a greater, and from others a lesser number of nearly perpendicular fissures, or rake veins, meet and join in one

common centre, from which they spread out like radii to different distances from the main body of the shaft or cone; and these branches frequently contain rich bodies of ore, which being worked out, there remains a vast perpendicular arched cavity, as it were hanging upon pillars. There is nothing in the practice of mining so tremendous as the excavations of large accumulated veins which have proved rich in ore. The mining shaft, or pit for drawing up the ore, and for descending down to the works, is frequently sunk upon the vertex of the cone or perpendicular pipe; and when you descend fifty or sixty fathoms down in one of these shafts, you are then swinging in the middle of an immense void space, where you see on all sides rugged, frightful, hanging rocks, which threaten to fall upon you and crush you to pieces. The excavations of the perpendicular irregular pipe is of itself sufficiently frightful; but when the hanging rocky sides of the main pipe or cone are opened up, perhaps from top to bottom in many places, in working the collateral diverging veins, the appearance of this horrible gulph is then frightful beyond description.

There is, as I hinted above, a variety of the accumulated vein, which resembles an irregular inverted cone, or the inside of a glass-house turned upside down. Some of these inverted veins are found so wide at the surface of the earth as to show at first no appearance of a vein, as nothing

is seen but a prodigious nest or heap of ore huddled together, until they go down some considerable depth, and then the ore is found encompassed by rock on all sides; and though they continue considerably wide for some time, yet they grow narrower by degrees as we go down in them, until at last they contract within the compass of one of the erect pipe veins which was described above.

Some of the pipes are very irregular at all depths; sometimes standing nearly erect, and then turning to a slanting or a spiral position; and with respect to the capacity of this pipe, it often contracts and dilates again to various dimensions, and it sometimes opens out to an enormous width far down as well as at the surface, when it may be called an accumulated vein.

When a rich pipe is very wide at the surface, it may with propriety be called an accumulated vein, as there is often found in it a great body of ore as it were accumulated in one heap; and sometimes more treasure is raised out of one of these in a few weeks than can be raised out of some mines in many years, even when they are worked with profit, and the accumulated ore is generally raised with very little trouble and cost, in comparison of the expence of working other veins.

Many iron mines are found in this description of vein, and lead and copper ores are frequently worked in both the sorts of accumulated veins.

A rich body of lead ore was found and worked in Yorkshire a few years ago, in what I call the inverted conical vein.

CHAP. VI.

OF THE ACCIDENTS TO WHICH MINERAL VEINS ARE SUBJECT.

HAVING finished the natural history of the principal mineral veins, which are the chief repositories of the greatest quantities of the metallic ores, it may be proper now to notice, that mineral veins are subject to several accidents in the progress of working them; some of which, if not well understood, may occasion the entire loss of the vein; and, therefore, as it is possible that these troubles or accidents are not in general sufficiently well known to miners, they deserve to be attentively investigated.

I observed before, that the flat vein found between the strata is frequently liable to be twitched or squeezed out by the roof and sole coming together; but if nothing more happen, the vein, it is pretty certain, will open again, and will be found upon the same level when the squeeze or twitch

is cut through. Such gripes or twitches are generally pretty well understood by miners who have been used to flat works; but there are other troubles or accidents incident to these veins, which are not so generally known, or so easily investigated; such as dykes, slips, gashes or chasms, the same as are met with in the coal and coal strata, which have been already described; nevertheless it may be necessary to touch briefly at what has been said about them. The flat strata veins, as well as the seams of coal, are subject to be interrupted and cut asunder in two by whin dykes; by dykes of softer stone; by dykes of imperfect stone; by all sorts of clay dykes, wet and dry, hard and soft, homogeneous and compound, or mixed with gingle, gravel, &c. They are also subject to be interrupted by gashes or chasms, which are generally filled with gingle, gravel, sand, or loose earthy matter; and all these dykes and gashes are wide or narrow, difficult or easy to get over, the same as in the coal and coal metals. The strata or flat vein, as well as the seam of coal, will be found nearly upon the same level upon both sides of the dyke and of the gash.

These veins are also liable to be interrupted and thrown off their level by slips. When a flat or streek vein meets with a slip, it is thrown so many feet or so many fathoms up or down in the same manner as the strata of coal, where this trouble was fully explained. There is one material

circumstance relating to this slip in the streek vein, which I hinted at before, and will now repeat, viz. that a slip in the strata is always a rake vein; a slip in the seam of coal, in any other strata, and in the streek vein, is one and the same thing in natural history; therefore, when a streek vein is thrown up and down out of its ordinary course and level by one of the rake or slip veins, if the slip happen to be tolerably wide, and contain more or less of ore, or of other promising mineral soil, there is in that case no danger; it may rather be thought a lucky accident. The miner will follow the rake vein up or down whichever way it has thrown the streek, until he meet with it again, and then he will work one or both of them as they prove productive: But, on the contrary, if the slip or rake vein happen to be in a close twitch in that place, and the two sides of the fracture be close and cemented together, in that case there is the more danger, as some of these slips which throw the strata and flat veins a great many fathoms up or down, are so close and imperceptible, that the flat vein may be lost without great attention. Exactly the same circumstances will happen in this case in the flat vein as in the seam of coal. When the vein is cut off by the slip, and thrown off its former level, the miner meets firm stone in the face, instead of the vein; and when he touches this stone, if he be perfect in the history of the strata above and below the vein, and

recognize the stone which meets him in the face, he can then make a near guess how far the vein is thrown off its former level. If it be a down slip, the vein will be first cut off above; but, on the contrary, if it be an up slip, it will be first cut off below, and there will always be a small vestige, although it be only a close joint, to show which way the vein is gone; but if he be not well versed in the history of the strata or binds, so as to know how far the flat vein is thrown off its former level, it may be necessary to follow the closest vise or vestigia, to prevent the danger of losing the streek or flat vein. The streek will stretch or spread out again upon the other side of a slip, much the same as it did before it was cut off by it. These breaks and irregularities of the strata are generally distressing troubles in the coal-field; but they do not always prove such harassing occurrences in the mining field; very often they are quite the contrary. I have seen ore upon one and upon both sides of a whin dyke; and the gashes in the strata, as I hinted before, often prove very rich and fruitful veins.

The slips, which are the most numerous of all the interruptions of the regularity of the strata, are also the most frequent and the most durable mineral veins; so that there is always, at least, the greater chance the more of these interruptions of regularity are found in a mining field; and

for a very good reason, because they are all mineral veins.

The rake veins, or perpendicular fissures, are frequently checked and interrupted by the sides of the vein coming close together, both in the longitudinal and perpendicular direction; and in these checks or twitches, the sides of the fissures are often so closely pressed together, that every vestige of a mineral vein is sometimes entirely squeezed out. However, as I observed before, experienced miners are so accustomed to these twitches, that they are seldom in danger of losing the vein by them, excepting in the case of their continuing too long, there being always some dark imperfect vestige of the course of the vein remaining, though sometimes hardly perceptible, the two sides being in such close contact.

But the perpendicular fissures are subject to start aside to the right or left hand, which is sometimes a more dangerous accident than the twitch, because it is in general less known. When one of these perpendicular fissures starts aside, the miner meets solid stone in the face, and the vein is squeezed out as effectually as in the common twitch; and there is moreover this material difference between the two accidents, viz. when a vein is squeezed out by a twitch, there remains some vestigia of the vein keeping the same perpendicular position and longitudinal bearing as the vein, before it came into the twitch; but, on the contra-

ry, when a vein is cut off by a start, or is thrown to one side, there remains not the least joint or vestige of the vein in the line of its former course, because it is thrown into one side quite out of its former bearing, and therefore it is the more necessary in this case to examine carefully all circumstances relating to this accident, as there are, I am persuaded, many good and valuable veins entirely lost by it.

A rake vein is thrown off its course to one side, either by a close joint, or an open cross vein. When a vein is thrown out of the line of bearing, into one side or other, it is proper to observe, that the vein in this case is always cut off by a smooth joint, which meets the miners full in the face, instead of the vein; and behind this joint, straight forward in the line of bearing, there is not the least appearance of the vein, because it is entirely thrown off its former course.

There is one circumstance relating to this back joint which deserves to be particularly remarked, viz. If the vein be thrown to the right-hand side, the smooth joint which cut it off meets the miner first on the left hand; and, on the contrary, if the vein be thrown to the left hand, the joint meets the miner first on the right hand, and so passes on in a slanting or diagonal direction across the forehead of the mine, or foremost working in the vein: That is to say, a perpendicular joint, or close fissure, throws the vein to one side in the manner

now described; but if it be a horizontal joint, it comes in across the soles, and the vein is cut off horizontally, and lost entirely in the former direction in working downwards in it. The same rule is to be observed with respect to the horizontal start as the perpendicular, to know into which side the vein has slipped or started. The horizontal start or joint which cuts off the vein in going downwards, does not cut it off in the true horizontal line, but leans or declines a little some way; and we may be certain that the vein has gone the same way as the joint declines. I believe it may be asserted, that the horizontal start throws the vein generally into the hading or ledger side. It deserves further to be noticed, that this starting joint not only crosses the whole breadth of the vein, where it is cut off, but also continues its course forward into the side, until it come to the vein again, to which it infallibly leads, if properly followed; and when the vein is found again upon the other side of this start or slip, it always resumes the same position, and bears to the same point of the compass, as it did before it was lost, or thrown aside. It will frequently happen in this case, that the miners will cut through the smooth joint which is the vestige of the start; and for a while they may work forward into solid rock, in the line of the bearing of the vein, until they begin at last to suspect they have lost it. If there be a small string of ore, or a streak of good mi-

neral soil in the joint or vise of the start where it enters the side, there is not so much danger as if it were only a close joint; as in that case, when they are tired of working forward in clean rock, without the least appearance of recovering the vein, they will return to the appearance they left behind in the side, which, being better examined, will lead them to it.

But if the vestige of the start is only a close joint, without any thread of ore, &c and they continue the mine or drift forward through it, it is a hundred to one if further notice be taken of it, and so the vein is for ever lost. I verily believe that many valuable veins are lost by this accident; for it is a certain fact, that these joints or vestigia of the start are often very close, and may be thought not worth noticing, which is my reason for being so particular on this point.

In the 2*d* place, when a vein starts into the side, off its former course, by the interposition or intersection of another open vein, the course and bearing of which is across the former vein, which is cut off and thrown aside, there is not much danger, as the miners will readily follow the interposing or intersecting vein, whether it bears much ore or not. It must have either ore or a quantity of mineral soil, if it be an open vein, that is, if it be a vein of any tolerable capacity or width; and the miners will follow the soil without ore in search of their lost vein, especially if it has been

rich; and if the new vein which intersects the old one prove rich, it is in that case a lucky accident.

CHAP. VII.

OF OTHER REPOSITORIES OF METALLIC ORES.

HAVING finished the natural history of mineral veins, it now remains for me to say something about the other beds of metallic ores; and the principal of these are two, viz. 1*st*, Such as are found in the body of the solid rock and strata, blended and mixed with the substance and composition of the stone: And, 2*d*, Such as are found upon the face of the rock, which is called float ore.

I. Gold is chiefly found in larger and smaller grains, blended with the composition of the rock; and this is the original cause of so much gold dust and grains being found in the beds of rivers. The surfaces of most rocks weather and decompose, and the decomposed parts are carried down by the currents, and lodged in the beds of rivers; and the grains and particles of gold being the most

ponderous, there is proportionally less of it carried forward to the borders of the ocean than of the lighter sand and gravel. It deserves to be remarked, that gold found mixed in the body and composition of the solid rock differs in quality or condition from lead or copper, &c. found blended in the rock in the same manner. In whatever place or quantity gold is found, it is always found pure and malleable; whereas the other metals are generally found mineralized, that is, mixed with sulphureous, arsenical, and other heterogeneous particles, which render them brittle and impure.

Lead, copper, and other ores, are also found in the composition of the solid body of the rock in many places. I saw a stupendous rock at a place called Cwmystwith in Cardiganshire, Wales, where so much lead ore was found blended in the rock as to be worth working and separating from it.

The rocks at Cwmystwith are of great height, and I saw the miners there suspended in ropes blasting down the rocks with gunpowder, and a number of busy hands breaking the compounded stone and ore small, in order to separate the ore by washing and dressing. I believe it always happens, that where ore is found blended in the composition of the solid rock, any joints and fissures found in such rocks generally contain some ore. This was the case at Cwmystwith. Some veins

and strings had been wrought long before, and at this time they were going on with some of them.

This part of the work was extensive, and in several places they had cut down the rock, so as to have very good footing for carrying on the work. It is so long since I saw this singular work, that I do not now remember certainly of what species or quality the rocks at Cwmystwith are; but I still retain an imperfect idea that they are lime-stone.

One of the most remarkable rocks containing metallic ore in the composition of the stone, is the breccia or pudding-stone at Gourock, near Greenock in Scotland *.

Both lead and copper are often found in lime-stone quarries in several countries, and I have seen very good lead and copper in lime-stone in several parts of Scotland; but I do not know how it happens that few of these fine appearances in lime-stone have as yet turned to good account in this country. The copper ore found at Currie in the Lothians, and at Kissern in the Highlands of Ross-shire, is remarkably good in quality, and

* The ore found at Gourock is copper ore in the state of carbonate and oxide. The rock in which it is met with is a coarse-grained sandstone; and the ore is so blended with the stone, that I observe, in some specimens in my possession, it has communicated to the whole mass a greenish colour. This ore has not been wrought for several years.—EDITOR.

trials have been made, and copper raised in both places, but not in sufficient quantity; and yet the copper at Kissern is of the best quality, perhaps, of any ore of that metal found in Britain. Good lead ore has also been discovered in lime-stone, and partly wrought, near Bathgate, and also near Calder and other parts of Scotland, but not with such success as to constitute durable mines, excepting at Bathgate, where formerly there was a rich lead mine, which yielded a considerable quantity of silver. The mines of Islay, which are in lime-stone, I am confident would be both durable and lucrative, if they were carried on with skill and spirit. Whether the ore in lime-stone in other parts of Scotland is really not to be found in sufficient quantity, or that the trials upon the several appearances have been made without sufficient skill or perseverance, I will not pretend to determine; though there is great room to suspect that this is the case, when it is so well known that many lasting and profitable mines are found in lime-stone in other countries. Mineral ores are found blended in the composition of several other species of rock besides lime-stone. The tin grains are found mixed in the composition of the granite rock in Cornwall; and I have seen lead ore mixed in the composition of the mountain rocks in the Highlands of Scotland and several other places.

There is a singular stratum of stone near Lossy-

mouth, in the shire of Moray, of about eight feet thick, which is compounded of several species of hard and fine stones of various beautiful colours. This stratum is a species of breccia, or pudding-stone, in the composition of which there is blended, in some parts of it, about an eighth part of good blue lead ore, of the species called potter's ore.

This curious bed of stone lies in a horizontal position, and dips away towards the north, under the Moray Frith, with an easy slope; and the lead is found in larger and smaller grains and flowers blended through the whole body and composition of the stone, in the same manner as the small masses of agate, white and coloured crystals, and other species of stone, are found blended through the whole body of the stratum.

I cannot help being persuaded, that perfect metallic ores being found in the body and composition of regular strata of lime-stone, and in other solid rocks, is not only an argument, but a clear decisive proof, that the materials which formed the several ores, and their concomitant spars, were poured into the veins and taken up into the composition of the strata of stone when they were first formed; and although many fanciful notions of the subsequent formation of solid ores in the cavities of mineral veins may be advanced, it is impossible to give any good reason for several species of ore being found blended with rider, spar,

and stone in the cavities of such veins, and in the composition of the solid rocks which form the sides of the veins; much less can good and perfect ore, found blended in the body and composition of various strata, be rationally accounted for, without acknowledging that such ore is coeval with the strata and veins in which it is found; and the float ore found in some mining fields is a farther proof of their being coeval.

Float ore is always found either spread out thin, or accumulated in hollow places upon the superficies of the rock, frequently with a bed of clay above it, and sometimes a considerable depth of gravel, sand, or earth above the clay. Float ore is always water-worn, like stones and gravel by the sea-side or in a river. It is found like water-worn bullets and gravel, of all sizes. I have seen in Flintshire rounded masses or lumps of it up to two or three hundred weight and more; and in the same float some of all sizes, down to small gravel, and part of it so small as to go through the sieve in washing; and it is always found mixed with water, rounded stones, and gravel of all sizes.

Now, float ore, which is so called from its being always found floating upon the face or surface of the rock, is never discovered higher, or upon a level with the vein or veins of that field, but always in lower ground near them; and it is always of the same quality, species, and grain, as the ore

found in the veins above; which is a clear proof that it was torn off the superficies of those veins by water, and that it was agitated in the water until all the asperities and sharp angles were worn off, and until it settled in hollow or level places upon the surface of the rock, from whence the water could not easily lift and remove it again; and the clay, gravel, earth, &c. were afterwards lodged above it by the future streams and agitation of the water.

It is to be regretted, that the natural history of float ore, and the methods of discovering it, are not more generally known, as I am persuaded it is to be found in many places which never have been searched or thought of. I have seen float ore in many places where no trials were ever made for mineral veins, or to know if the float was rich or not. But it may be proper for me to observe, that there is a very material difference between float and shoad ore, although they are both found upon the surface of the rock. Shoad ore, so called by miners, is always found in loose masses of all sizes, either in or under the upper soil; sometimes upon the top, basset, or out-cropping of the vein, but more frequently a little to the lower side, where there is a declivity, and where the vein crosses the slope.

Float ore differs from the shoad in being water-worn, which is not the case with the latter; and, moreover, the float ore is generally mixed with

water-worn bullets and gravel, which the shoad never is, unless it happen to be washed off the superficies of the vein by some rivulet or stream of water.

Shoad ore is a pretty sure indication of a vein where it is found, or a little above; but you must judge of the distance above by the greater or less acclivity of the slope. If the side of the hill be very steep, it may slide a great way down; but if there be but little declivity downwards from the vein, the shoad will be found proportionally at a less distance. The shoad ore is found of all sizes, from very large masses down to the size of peas and smaller grains, and it is produced by the weathering or decomposing of the sides of the vein, so as to have the ore standing higher than the superficies of the rock, which in time slides off where the ground is sloping. It is a common thing in some mining countries for the miners to go a-shoading, that is, to go a-searching for the shoad, when they will traverse rivulets, gullies, scars, and other places where the surface of the ground is broken, or where the strata rise up to the grass roots; they will even examine newly ploughed land and molehills, and not always without success. From the history or description of the float and shoad ore already given, I have no doubt that an intelligent person, though no miner, will be able to distinguish the one from the other; but in case either of them should be found, it may be

proper for me to point out the proper methods which should be taken to discover the vein. Shoad ore is found in rough irregular glebes, or angular masses of all sizes, frequently coated with white upon the outside. When such happen to be discovered upon a flat level piece of ground, a cross trench should be cut to the rock in the very place where it is found, thus +; but if you find it upon a slope, or immediately at the foot of a slope, then you are to look for the vein at a less or greater distance above, in proportion to the slope or declivity of the ground. When shoad is found upon a slope, or at the foot of it, your first business is to look about you upon all hands, to see if you can discover any other symptoms of a vein; and if not, then you must judge from circumstances what method you should choose to discover the vein. If you find that the cover upon the superficies of the rock is thin, and the distance from the place where the shoad was found to the highest part of the slope is but short, you may begin a cut to the rock upon the spot where you found it, and push your trench right up the slope, keeping the surface of the rock until you discover the vein; but if you should fail to discover the vein by cutting upwards in a right line, come down again to the foot of your trench, and there cut a little across, in case the vein should run in a right line up and down parallel to your cut, or in a diagonal direction, and you have been a little to one side at first setting out. If the cover upon the superficies of the rock

be thick, it will in that case be troublesome and expensive to cut a long trench; and therefore your best method is to sink a small shaft down through the cover until you come to the solids.

You must take particular notice of every thing you see in going down with this shaft; and if you find bits of ore, of spar, or of good vein-stone, it is to be supposed that you are still below the vein; but if you can discover no mineral soil, or any symptom of a vein, neither as you go down nor in the superficies of the rock, you have perhaps overshot the vein, and must come lower down, and sink another shaft about half way between the first and the place where the shoad was found; on the contrary, if you find bits of ore, or lively mineral soil, in going down with the first shaft, in that case you are to sink another still further up, in the line of the first, from the place where the shoad was found; and if the symptoms continue stronger in the second shaft, a third, a fourth, &c. must be sunk, still keeping the line. You may happen to hit the vein in one of these pittings; but there is a chance of twenty to one against it; nevertheless, if there be either a good show of ore, or of other mineral soils above you, the symptoms will increase in quantity as you advance nearer the vein; and therefore it is your business to continue the pittings until you either touch or overshoot the vein. When you find that you certainly are above all your symptoms, come back half way to the next shaft containing them; and if you find them again more

plentiful and lively, then you should carry a drift upwards, keeping or baring the face of the rock in the sole of the drift, until you cut the vein; but if you miss the symptoms in this retrogade shaft, then you should drive the mine, as just now directed, from the bottom of the last shaft which contained them. It should be carefully noticed, if all the symptoms you once had continue or not as you advance upwards with the line of pittings. If some of them only continue, and you miss others which you had below, there is a presumption that you have overshot one vein, and that there is still another above you. In this case it is your business to advance upwards, as already directed, and to come down again to the last shaft which contained all the symptoms, and carry a drift from it upwards, until you cut the vein which is overshot.

If the symptoms should appear stronger in one side of your shafts than in the other, it is probable that the vein runs up and down the slope parallel to your line of pittings. In this case you should go to the shaft which contains the most and best mineral matter, and drive across upon the face of the firm rock into the most promising side; and if the symptoms increase as you advance, push forward your drift until you cut the vein. I have already observed, that if your prospect is good, the mineral symptoms should increase as you advance nearer the vein with your line of pittings. The same observation will hold in trenching, where

the cover upon the face of the rock is thin enough to admit of adopting that method of trial, which is the simplest and surest of any, where circumstances favour it. If the symptoms increase as you advance with your trench, you are sure that the vein is still before you, and must persevere while they continue; but if they appear stronger in one side of your trench than in the other, you should cut less or more across in the promising side, as circumstances encourage you, keeping the forehead of your main trench open, in order to continue it, in case you do not succeed in cutting across.

With respect to the float ore, I do not think it safe to advise any method of trial for the vein from which it originally came, until such vein is otherwise first discovered, it being very difficult to know how far the ore has been carried by the water before it was lodged in its present bed; and, therefore, I would advise a diligent search on all sides, especially towards the higher grounds, to see if any other symptoms of a vein can be discovered before you proceed to expensive trials. But notwithstanding this caution, it is highly proper to make trials upon the float ore itself, in order to discover what quantity may be found, that you may be able to judge whether or not it is worth pursuing.

In trying the float ore, it is proper for you to

make a trench or cut in it quite down to the surface of the rock, and to push your trench forward the way that most ore appears. It is likewise proper to push forward cross cuts from your first trench every way where any ore leads you, as there may be nests and accumulated parcels of it lodged on either hand where it is not expected; and, therefore, it is proper to follow every symptom, and to examine every probable spot, especially flat or hollow places. Float ore, and likewise shoad ore, may at first be turned up by the plough, and by the spade in making ditches, canals, roads, &c. It may also be discovered in accidental or continued runs of water, and in any other places where the surface of the ground is broken.

In whatever way it may be discovered, it is proper to make every kind of trial upon it by trenching to the rock; and if the cover of clay, gravel, earth, or any other loose rubbish which lies above the float ore, should be in any place too thick for trenching, in that case you should put down pittings upon it here and there; and if a quantity of ore is discovered worth working, you are then to judge whether you can raise it cheapest by throwing off the cover, so as to lay the whole ore bare, or by mining it under ground, and securing it with timber. Whatever method is chosen, as the ore lies upon the surface of the rock, it is to be observed that there is a chance

of discovering a vein in trying and raising the float ore.

Where either float or shoad ore is found in a settle or small flat spot, in the middle of a sloping piece of ground, or near the bottom of a slope, there is a very good method of trial, besides trenching and pitting, called *hushing*, which is often practised with great success; and where circumstances are favourable, it is undoubtedly the most effectual, and at the same time the most frugal method of trial, for making mineral discoveries; but several circumstances must concur to make hushing convenient. In the *first* place, a considerable slope is absolutely necessary; and, in the *second* place, water must be collected in some convenient place for making a dam-head or reservoir, and the higher up such a head can be made the better; but the dam must be so situated that small collateral diagonal cuts may be made across the slope, on both sides, to conduct the water from small rivulets or higher springs, and also rain water, into the reservoir. If a little dingle, settle, flat, or hollow place can be had for the site of this reservoir, so much the better, as the head can in that case be made with less expence to hold much water; but where such a spot cannot be had, a reservoir is often made upon the declivity, in the form of a crescent. A large dam is always better than a small one, if it can be had; and where the sloping ground to be hushed is of any consi-

derable length from the hush-dam down to the bottom of the slope, the reservoir must contain a considerable quantity of water, otherwise its force will be spent too soon before it proves effectual to carry down the great quantity of rubbish which the water will raise in a long hush-gutter; and, therefore, if the dam have not a level area for the water to spread upon a considerable superficies, it is necessary that the head should be the higher, in order to make up in depth what is wanting in the length and breadth of the piece of water. I will only hint in general, that the head of this reservoir and the sluice must be wide in proportion to the quantity of water to be let out at once, and to the strength of water necessary for scouring the hush-gutter.

From this hush-dam you draw a line right down the hill, unless there be some hillock or other obstruction by the way; in which case you must draw your line in such a direction as the water will run best in a trench or hush-gutter when made. When you have marked out the line of the hush-gutter all the way down to the bottom of the slope, then you must cut off the sod or upper surface of the ground out of it, about two or three feet wide, and about a foot or a foot and a half deep, all the length, to make room for it to contain a small run of water; and when the gutter is so prepared, you must let out but a small quantity or run of water at first, in proportion to the

capacity of the gutter; and when the water is let out the two or three first times, the men must be divided at proper distances from one another, with their tools in their hands, to help to loosen the earth for the water to carry away, and to remove obstructions to the current in the gutter. When the water has run out, stop up the sluice, and turn such stones out of the gutter as have not been removed by the water, until it is wider and deeper; and clear the gutter of all other obstructions which the water cannot remove, until it has greater weight and force than there is room for in this state of the hush. Let the water be increased every time it is let out, in proportion as the gutter wears deeper, to be capable of carrying more of it, and let the men continue to assist the water as long as the gutter is shallow, and it is safe standing upon the edges of it, which it is not when the gutter is worn so deep as to contain a strong hush of water. By only removing the big stones and other obstructions after every hush, the frequent application of the water will wear down the gutter to a great depth, generally without any digging or farther trouble than lifting and closing the sluice, and keeping the gutter in repair. When stones too large for turning out whole are discovered in the gutter while it is shallow, they must be blown in pieces with gun-powder; but when the gutter is worn deep enough to hold a strong hush or current of water, it will carry down an

amazing quantity of stones and rubbish with incredible force. The steeper the declivity, and the longer the gutter is, the greater force it has. I have seen stones of several tons weight, and as big as little huts, carried several hundred yards down a large hush-gutter; and the water and stones of all sizes which the water carries down, wears at last not only the surface cover, which lies above the rock, but it also wears down, by the friction of the stones, a considerable depth of the superficies of the rock itself, and, of consequence, it must discover and wash clean all the veins, useful and curious stones, &c. which cross the line of that gutter in any direction, by which means valuable discoveries are often made; and where water can be had, and can be properly used, hushing is a more effectual method of trial than either trenching or pitting. When a hush is worn pretty deep, where there is a weighty cover above the superficies of the rock, sometimes great stones or other obstructions turn the water to wear the one side of the gutter more than the other; and sometimes both sides wear, undermine, and fall in alternately, until the water is spread so wide in that part of the gutter that its force is lost. In these cases it is necessary to turn the big stones to one or both sides, so as to give the water room to run as near as possible in a straight line, which is the only way to make it scour the bottom effectually.

But notwithstanding all that I have said about turning out and removing stones in the gutter, it must only be understood that this is necessary and proper in two cases, viz. to turn the large stones at first, when they are a real obstruction before the gutter is sufficiently capacious, and the stream of water strong enough to carry them down; and to turn them aside afterwards, to confine the water in the middle of the gutter. Excepting in these circumstances, the more stones the water has to carry down the better; and therefore, when the hush is over, the men should be employed to loosen the stones out of the clay, to blast such of them as are too large into smaller pieces, all of which should be left in the gutter for the next hush to carry down; by the force of which, the clay and other rubbish will be torn up and carried off, and the surface of the rock bared and worn down. When there is a little flat, or an easy slope immediately below the sluice, and the form of the ground otherwise admits of it, two, or even three hush-gutters may be made, and scoured with the same reservoir, by turning the water off to one side at first, and giving it a different direction; by which means more discoveries may be made, not only of other veins, but also in other parts of the veins discovered in the first hush-gutter; for it often happens that the same individual vein, which proves barren in one place, produces good

ore in another place, at some distance in the line of bearing.

This method of discovering mines by the help of water, in the manner I have pointed out, must be very effectual where the ground, and other circumstances, are convenient for this mode of trial; and I like it the better, as it may be said to bare to the bone, and show every thing that is to be seen in that section of the hill.

CHAP. VIII.

OF THE SYMPTOMS OF MINERAL VEINS.

I will now proceed to point out some of the other appearances and symptoms of mineral veins, besides that of finding float and shoad ore upon the surface of the ground.

Mineral veins may be, and frequently are, discovered in all places where the superficies of the strata and rocks are to be seen; such as, upon the rocky shores of the ocean and of lakes, in rocky precipices, in the rocky banks and beds of rivers and rivulets, in dingles or ravines, and scars, and in all other places where the solid superficies of the strata is either to be seen, or has so thin a co-

er that some of the mineral shoads are found ixed with the upper soil. But where there is a ick cover of clay, sand, or other loose matter, pon the surface of the rock, all mineral symp- ms are then perfectly concealed from our view, ntil such cover is cut through by some ditch or ench, or washed away by some rivulet or cur- nt of water, &c.

As a perfect knowledge of the real symptoms of ines is of material consequence, I will attempt a escription of the external appearances of mineral eins, and of the several sorts of mineral fossils, hich, having slidden off the surface of veins, are dications of the veins being near the place where ch mineral substances are found; and if these ints are sufficiently distinct, men of observation ay make useful discoveries, when traversing dis- icts either for pleasure or business, where the su- erficies of the strata is to be seen.

The rake vein, or perpendicular mineral fissure, eing the most common in all countries, I will be- in with it: And with respect to external appear- nces and symptoms, rake veins should be divided nto the *hard* and the *soft*, because the indication nd the contents of each are different, and will be asily distinguished.

A rake vein is a gash or fissure which cuts the ocks and strata asunder in some certain line of lirection; but as the space between the sides of a ein is commonly filled up with some mineral mat-

ter or other, it requires attention to distinguish the back or basset of the vein from the rest of the circumjacent rocks.

Wherever the regularity of the strata is interrupted, or any breach or fracture appears in the rock, there is reason to suppose that it is occasioned by a mineral vein; and therefore, when a considerable gash or crack is observed in the face of a rock, or cutting across the strata, it should be taken notice of and examined. The fissure of a vein may be distinguished from such a recent crack as is occasioned by the undermining of water, or by the gradual yielding of a precipice. The sides of an accidental recent fissure are generally rough, unequal, and jagged, and the chasm or space between the sides is generally empty, at least of mineral matter; whereas the sides of the mineral veins are more regular, and may be traced in pretty straight lines, whether the vein stand nearly perpendicular or in a slanting position; and the space between the sides, whether the vein be narrow or wide, is always filled, either in whole or in part, with ore, or with such other mineral fossils, hard or soft, as accompany ore in the veins.

When a hard vein is discovered in the face of a precipice, in the bed of a river or rivulet, or in any other bare rock, if no ore be immediately found in it, the first thing that should be attended to by an unskilful person, is to find the true sides

of the vein, which sometimes are easily distinguished; but this cannot always be so readily ascertained, because false sides frequently appear in the middle of a bold hard vein, by the interposition of a rider, or of other stony matter, which apparently divides the vein into several parts. When the true sides of a vein are found, upon the outsides of which the rock or strata again appear regular, then the contents of the vein should be carefully examined. Some hard veins contain nothing between their sides but hard mineral substances, and others contain, besides, a thin stratum or sticking of soft mineral soil, either near the middle or in one side of the vein; and some wide veins contain more than one stratum of clay, or other soft soil. The mineral substances commonly found in hard veins are vein-stone, spar, and fluor, along with the metallic ores.

Lead ore, exposed to the open air in the surface of a vein, seldom exhibits its native colour and brightness, but is found either coated or tarnished; however, when struck with a pick or a hammer, it discovers a vivid colour and shining appearance. In very hard veins the lead ore next the surface, which is exposed to the air and weather, is generally tarnished of a dun or greyish stony hue, without exhibiting the least indication of any thing metallic until it is broken, when its brilliancy will soon appear; and therefore, when a hard vein is discovered, every substance found between the

sides, of whatever colour or appearance, should be very carefully examined.

The mineral substances commonly found in hard veins, besides the metallic ores, are the vein-stones, spars, and fluors. The spars found in hard veins are calcareous spar, cauk, or heavy spar, and quartzy spar. The several sorts of spar are pretty easily distinguished from other common stones, being commonly of a white, a brownish, reddish, or of a yellowish white colour; of a peculiar structure, being either of a tesselated, rhomboidal, scaly, or tabular form, in the inside of the masses, especially the lead spars; and some of these spars which are found in mineral veins are semi-transparent, and others opaque.

The vein-stone or rider has always an irregular appearance. The purest and whitest specimens of this stone have some resemblance to a burr, and it is often equal to the burr in hardness; but this stone is seldom or never so uniform and regular in its texture as the burrs, being frequently compounded of different species of mineral matter, such as the bases of the stone itself, which is generally of a siliceous quality, with several sorts of metallic ores, pyrites, spar, fluor, &c. blended in a hard, rugged, heavy stone, which is sometimes solid, and sometimes cavernous, and the cavities are frequently lined with druse, or clusters of transparent pointed crystals. When the vein-stone is compounded of different kinds of mineral

matter, it often exhibits different colours in the same mass; but when it is mostly of one sort of matter, it is generally of an uniform colour; but whatever be its colour, it has always a rugged appearance and form, and indeed looks like a vein-stone, and not like any other stone *.

The fluor or flux stone resembles some of the finest species of spar. The fluors have generally a fine glossy appearance, are of various beautiful colours, as white, blue, green, yellow, violet and brown, with various shades and tinges; and are always of a fine glass-like appearance, and generally of a cubical, a rhomboidal, or of a laminated structure, and sometimes of an irregular form; but whatever be the form or colour, fluor may be known and distinguished by its weak and glassy constitution, and by its elegant appearance, being generally either diaphanous or semi-transparent.

When one or more of these hard mineral substances are found scattered upon the face of the ground, it may be presumed that a hard mineral vein is not far off, as these may be called the shoads and indications of the vein. When these mineral fossils are found in such plenty as to at-

* The vein-stone described by the Author seems to be quartz, which often occupies a considerable portion of mineral veins. The term *vein-stone* is here employed in a very limited acceptation; for, in its usual sense, it includes every kind of stony matter which accompanies metallic ores in veins.—EDITOR.

tract the attention of the observer without seeing a vein, the figure of the ground must then be considered, in order to judge of the situation of the vein from which these substances come. If the ground be pretty level, the vein may be found by digging immediately under these shoads; but if there be a declivity, the vein undoubtedly is situated higher up; and therefore, if it be judged proper to search for it, I have pointed out the proper method of trial above, when treating of the shoad ore. When any of these hard mineral substances are found in a river or rivulet, the vein should be found either higher up crossing the stream, or in one of the banks running parallel to the stream, because all these substances tend downwards in the course of time, by the sliding of the banks, the flow of water, and the gravity of these several bodies.

The preceding description supposes a mixture of stony matter in the hard veins; however, there are hard quartzy veins in many countries, with and without ore, in which no stony matter appears but the quartz itself. The ore in quartzy veins is either blended in the quartz, or more solid; but whether solid or mixed, lead ore in quartzy veins is always bright and shining in the inside when broken, though it is generally dull and tarnished upon the outside when exposed to the external air.

The quartz in these hard veins is generally

pretty white, of a fine glossy texture, and remarkably hard and heavy; and when any caverns are found in these veins, they are filled with crystallizations, which are hard, transparent, and pure. Quartzy veins are frequently very wide and strong, with distinct sides, which may be discerned with certainty by an experienced eye, accustomed to take notice of the external appearance of mineral veins. Many quartzy veins are so strong and bold, as to rise up in a ridge above the surface of the ground, or surrounding rocks, and be distinguished and traced in the line of bearing a great way through the mountains. I have frequently traced such veins for two or three miles in mountainous rocky countries; and it generally happens, that some ore of lead or copper is to be found in one place or other, and sometimes in several places in the surface of such veins; but by reason of their excessive hardness, it seldom happens that any trials are made in such veins, unless the ore be found at once at the surface in sufficient quantity to be worth working. But if any superficial trials should be made in some of these hard veins, they are generally attempted by unskilful workmen, who can make little or no progress in so hard a stone; and this baffling all their efforts to sink down or to drive forward in it, the work is given up before any satisfactory trial is made. For these reasons, most of our very hard quartzy veins remain entire, for the use of future generations, when

our mines which are easily worked are either exhausted, or too deep for draining out the water; as I have no manner of doubt that there are valuable treasures in many of these veins lodged at different depths, in some near the surface, and in others further down; and in general, we are assured from experience, that the further down, the better for plenty of good ore.

There is yet one sort of hard vein, the external appearance of which has not been described, and yet it is very material to be known, being frequently the most productive of all veins. The vein I mean is found in such mountain rocks as exhibit nothing but *rachel*, or a loose shattered broken rock at the surface, which falls into small angular masses of irregular figures. It is very difficult to point out the appearances of this vein where it bassets out, by reason of the loose and broken state of the rock near the surface of the strata. Where the rocks are thus loose and broken at the surface, and fallen to small irregular masses, or mouldered down to rubbish, it requires great attention to investigate the symptoms in such ground so as to find the basset or surface of the vein. In rocks that are thus broken down to rubbish at the surface, spar, vein-stone, and other symptoms, are sometimes scattered about pretty wide, and the more so, if the ground have much declivity. This debris of the broken rachel, and of the mineral symptoms thus scattered loose about

the surface, is called by Cornish miners the *broil*, or the *broil of the vein.*

When veins in such rocks are not very wide at the surface, there is then no room for any considerable quantity of mineral soil, and therefore the mineral symptoms cannot be strong; and when the rock is fallen to loose rubbish, the mineral fissure and mineral symptoms are scattered in small strings among a number of vagrant cutters, which are disjointed by the separation of the loose and broken rock; in which condition, a vein that is not very wide above is often difficult to be discovered, even by a skilful eye, and no doubt many such veins are overlooked.

But notwithstanding these causes of obscurity, some vestigia of the vein are always to be found, if carefully attended to; some small masses of spar or vein-stone, or some other symptoms of mineral soil in the disjointed cutters; and where such are seen they should be attended to, and some of the rachel or shattered surface of the rock should be dug off, to see how matters appear below in the solid rock, where the vein will appear distinct between regular sides, and then its value can be in some measure judged of.

The top of almost all the veins where they basset out, in some of the best mining fields, is found in this description of rock at the surface; such, for instance, as the great mining fields of Leadhills and Wanlockhead, in Scotland, where the

debris of the loose and disjointed surface of the strata are of considerable depth, almost every where upon those mountains, which so conceals the basset or top of the veins, that some valuable rich veins are but lately discovered; and, in general, the basset of their richest veins is not seen, but they are discovered by cutting cross mines or galleries, either for levels to drain the water, or for the purpose of discovery.

The soft mineral soils are as various in quality and appearance as the hard. The first soft vein which I will take notice of is a white mineral soil or clay, which is sometimes fine and smooth, but often more friable and coarse to the touch, and not unlike slaked lime when mixed with sand. When this soil feels a little gritty, and there is tolerable room between the sides of the vein, a little of it should be dug out and well examined, by washing it in water, and by pounding it between two smooth stones, as this species of mineral soil frequently contains small masses and grains of lead ore, which is coated white, and so of the same colour as the clay; but by washing and pounding, some bright particles of the ore will appear, if any large grains are mixed in the soil; and if small masses of lead ore are found at the surface, by digging in a vein containing this soft soil, more may be expected below.

Red fat clay in mineral veins, which indelibly stains the hands and clothes, indicates iron, of

which I will say nothing in this place, but that the better species of iron ores are generally accompanied with red staining soft soils, by which they are easily distinguished. At the same time, it is proper to observe, that some lead and copper veins contain a considerable quantity of iron, and consequently of a red and a brownish red staining soil; and, therefore, circumstances require to be examined with skill and care in the case of discovering soft soil in a vein of a reddish colour.

The next I shall take notice of is a bluish, a grey, a greenish, or a brown tough clay, or sticking; and when these appear in small quantity, or in very thin seams between regular sides, which are nearly close together, that is, where the sides of the vein are uniformly close, with a thin vein or sticking of tough clay between them, without any appearance of ore, I would not advise much trial to be made in such veins, unless some more promising symptoms are discovered in some other places in them. But if the veins containing such soils be moderately wide, and less or more of spar or vein-stone, &c. appear with the clay, some little trial may be made in it; but I would not go far in such trials without finding some ore.

It is proper to observe here, that mineral clays and soft soils in veins are found of all colours and appearances, which makes it almost impossible to describe them all perfectly, so as to be able to

distinguish them from other common clays and soft soils; and, therefore, it is necessary, in the first place, to be able to ascertain with certainty that you have a vein, by seeing two sides and a regular continuous fissure cutting through the rocks in some certain line of direction; and if you can distinctly see a fissure cutting through the strata in a continued line, and can discern two sides, and see the clay between the sides, it is mineral soil, whatever the colour and other appearances of it may be.

But it is necessary for me, before I proceed any farther, to make another explanatory remark. I just now observed, that it is necessary to know that we have a vein before we form any judgment of such soft soils as appear like mineral soil; and the very same may be said of the hard mineral fossils, such as spar, felspar, vein-stone, &c. These often appear where there is no good and regular mineral fissure or vein; and, therefore, whether the mineral fossils discovered are soft or hard, their consequence depends upon the mineral vein which they belong to. But the remark which I am going to make is this, viz. that it is not always easy to judge from the external appearance of a vein at the surface of the ground, whether it is a good one or not, even where the superficies of the rock is seen, which will evidently appear from what follows. I believe I observed before, that those rake veins or mineral fissures which were caused

by a fracture and a breach in a line, and by the fracture opening asunder to a wide chasm, without any slip or sinking down of the strata upon one side of the chasm below the other side of it, are always widest above; and that those veins which were caused or produced by a chasm and a slipping down of the strata upon one side of it, are generally narrow above and widest below.

I have so often seen very close contracted veins at the surface open out below to various capacities, that there is no room to doubt the fact, which makes the first appearance of the slip veins in some situations very deceiving, and in some circumstances not easily investigated by the most skilful, so as to enable them to form a proper judgment. Where the rocks are hard, compact, and close, or free from numberless cutters at the surface, a rake vein may be known, even where the sides of it are pretty close together; but, on the contrary, if the superficies of the strata is a rachel, or loose and shattered, and full of cutters in all directions, the investigation of a vein which is close above becomes very difficult, sometimes almost impracticable, without some trial. I have frequently seen rocks, that were solid and regular at the surface, cut by veins so narrow above, that the two sides of the vein were close together in two parallel lines, and so near to one another, that to an inexperienced eye, the narrow and hardly discernible fissure would appear to be no more

than a common cutter; and yet I have very frequently seen these veins open out gradually as they went down, until they became some of the boldest and widest veins below; and I am persuaded, from what I have observed in my own experience, that many rich and valuable veins are overlooked and neglected, because they are narrow and confined above, and do not look promising at first sight; and, therefore, when one of those narrow veins is discovered, with a little ore in it, even no thicker than the blade of a knife, I would advise sinking some fathoms in it, as very probably it will open out below; and if it begin to open a little at a moderate depth, there is then the greatest reason to expect that the sides will dilate to a sufficient width when you are farther down. But if neither ore nor spar, &c. appear at first in a regular contracted vein, then the line of bearing, or the point to which the vein trends, should be taken with an instrument or compass, and two or three trenches cut to the rock across the vein, in order to discover it at a distance, where it does not appear at the surface; as it is always found in experience, that veins appear and prove better in one place than another, at the surface of the ground as well as down below, and often carry ore and other mineral soils in one place, when scarcely any symptoms of the vein appear in another place, even at no great distance.

Soft mineral veins, which contain soft soils at

the surface, are easily known, provided a sufficient quantity of the vein be seen to enable the observer to determine at first sight that it is really a mineral vein and mineral soil, and not a bed of common surface clay, for these soils are not always distinguishable by the colour or by any other external appearance; and in some places, where only a little soft soil is to be seen in a scar, or other small break in the surface of the ground, neither the sides of the vein, nor any other symptoms of a vein, except the clay or soft soil, are to be seen without breaking ground to make some trial, and therefore circumstances should be examined.

If the superficies of the rock appear in other parts of the ground, not very far off, and if none of that clay or supposed mineral soil appear in those places, there is the more reason to suppose that it is the surface or basset of a vein; however, to make sure work, it will be proper to dig in it to discover the sides of the vein, if there be one, and to see if you can discover any ore or other promising mineral substance in it.

But I should warn you here not to be too soon discouraged if you should not find the sides immediately, as some soft veins are very wide, and contain a great breadth of the soft soil at the surface; and such wide veins deserve the more attention, as they frequently prove very rich.

The soft mineral soils in veins are found of all

colours and appearances, as white, black, and blackish, all the shades of grey, yellow, green, and marbled, &c.; but the most remarkable and distinguished of all the soft mineral soils, and frequently the most promising, is of a loose, light, and friable texture, often resembling rappee, and other snuff, in colour and external appearance when dry, it being sometimes blackish, but generally brown, in all the degrees and shades of that colour.

'When veins are regularly open and roomy between the sides, or open into irregular bellies and large cavities, containing considerable quantities of this brownish friable mineral soil, it is generally looked upon by miners as a promising symptom. But it is proper to remark, that the most promising symptoms in mining often prove fallacious and uncertain. The same mineral substances, or mineral soils, that accompany good ore in some places, will be found in good and regular veins in other places, and yet no ore discovered, or none to signify, by the most judicious trials; so that ore is the best, indeed the necessary symptom of a good mine.

Good ore may be, and often is, discovered by digging in a barren vein with promising symptoms; but if no ore has been found in the field, I do not hold it prudent to proceed very far in trials without finding some. At the same time, it must be acknowledged, that this soft mineral soil, which

miners call *chun*, *ghurr*, or *mother*, is the most promising, and is often found in great quantities in the best mines of lead and copper. In some good mining fields, where the veins are wide and roomy, and produce plenty of ore, it is not uncommon to find great quantities of masses of solid ore of various sizes lying loose in this sort of soft soil; and in some places where the cavities of the veins are exceeding wide, a single mass of solid ore is sometimes found so large as to produce a great many tons of lead.

Where these soft soils, or the hard broil of spar, vein-stone, and other symptoms of a mineral vein, are in such quantity, and of so good a quality, as to induce you to look into the vein, and you cannot readily discover the sides to direct you to sink a little in it with propriety, your best method in such a case is to cut a trench upon the place down to the rock, in the form of a cross, as directed above in the case of finding shoad ore upon level ground, which is the surest method of finding the sides and course of the vein; and when you have discovered these points, you will then be able to judge how you should proceed.

It has been observed, that mineral veins may be discovered in almost all places where the upper surface of the ground is so broken as to discover the superficies of the strata, such as in the rocky mountains and cliffs, in the rocky banks and beds of rivers and rivulets, in ravines or gullies, and in

all other places where the surface of the rock is visible.

Generally all the large caverns and smaller cavities upon the shores of the ocean are mineral veins. These veins, and the mineral soils contained in them, are much softer than the rocks which are cut by the veins; and being continually exposed to all the changes of the air and weather, and more especially to the rage of a stormy ocean, whose mighty waves dash against the shores with irresistible force and fury, the mineral soils are thus worn out of the veins.

When a vein points in any direction into the sea, the continual beating of the waves against it wears the mineral soil out of it by degrees, and then it becomes an empty cavern. These excavated veins are very numerous, almost all round the sea-coasts of Scotland, many of which I have entered and examined; and I have seen both lead and copper in numbers of them, many of which are very deserving of attention.

Some celebrated writers of natural history have asserted that mines and mineral fissures are only to be found in mountains and hilly countries, and that there are none in the plains and valleys, which is an erroneous position, absolutely false in fact and in experience. I have myself seen great numbers of veins upon the shores of the ocean, where the ocean was the boundary of extensive plains. I have also frequently seen them in the

beds of rivers, in places where the surface of the rock was washed; and I have often seen both lead and copper in them. I have seen very considerable mine-works carried on with success so low as in the beds of rivers, which were turned into new channels for that purpose, in North Wales, and in other places, which rivers were but a little elevated above the level of the sea. These instances are sufficient to prove the fact, and there is no arguing against observation and experience in such cases.

And, moreover, agreeable to sound philosophy, in the investigation of the phenomena of the strata, there are the same natural reasons for the existence of veins, and even in great numbers, in the plains as well as in the mountains. I will just now defer the tracing out and explanation of these phenomena; they will come in my way in some future inquiries in the Third Part of this Work; at present, I will only observe, that the position is dangerous as well as false, which is my reason for insisting upon this topic. If it be once received as an undoubted fact, that no mines or mineral fissures are to be found in plains and valleys, farewell to any inquiries about symptoms or attention to them. Upon this supposition, if good shoad ore were found in a plain, the reasoning mind would immediately suggest, that it was carried and dropt there by accident, and of course it would be overlooked, neglected, and forgotten.

Wherever the superficies of the strata is discovered in low plains, we see them as frequently cut by mineral fissures as in the mountains; and oftentimes the veins are more numerous in the plains than in many very hard and lofty mountains; and as ore is seen in veins, and worked in such low places, and as veins are seen as numerous in the rocky shores of the ocean, and running under the sea, as in many other situations, there is no room to doubt that mineral fissures, containing all sorts of mineral ores, exist in the low plains as well as in the hills and mountains; only the situation is not so favourable for discovery, the superficies of the strata being frequently covered in the plains by earth, sand, clay, and gravel.

But it may be observed here, that some plains are composed of strata in which metals or mineral ores are seldom found; such, for instance, are beds of chalk, of schistus, and of the coal metals. Metallic ores are but seldom found in any of these: I do not say never, as all the slips and dykes in the coal-fields are really mineral veins; and I have seen a little lead and copper ore in some of them. A valuable lead mine was wrought a long time at Coalcleugh in Northumberland, which, as I was told, is entirely in the coal metals, that is, in such strata as accompany coal: And, moreover, I was informed, that the lead vein at Coalcleugh actually cut off the stratum of coal, in the same manner as it is cut off by a common coal-dyke; and

that the coal was found to floor and stretch upon the other side of the vein of lead, as regularly as before it was cut off by it. However, this is an uncommon instance. In general, we know by experience, that freestones, argillaceous tills, and the other concomitants of coal, are unfriendly to the metallic ores. I have not seen or heard of any metallic ores being found in chalk; and although I have seen ore, in small discontinued quantities, in schistus, I never expect to see a plentiful and durable mine in it. It may be objected to this, that the iron-stone so frequently found in thin strata, and in nodules in coal-fields, is a refutation of what I have advanced, as this iron is found in such abundance among the coal-metals in many places, as to become the foundation of increasing manufactories; but it must be remembered, that this is iron-stone, not iron-ore. This stone, it is true, is found in great plenty in many coal works, and in the near neighbourhood of them; but it is as seldom found in the mineral fissures, that is, in the dykes, slips, gashes, in any considerable quantity, as any other of the metallic ores. This iron-stone is found in regular strata and in nodules, which have been broken off from the superficies of the strata, rolled in water, and afterwards lodged in the argillaceous strata of the coal-fields; and as this species of iron-stone so frequently accompanies coal, and is always found in the same circumstances of strata and nodules of

glebes, it must be reckoned as one of the coal-metals, or concomitants of coal. Iron ore, properly so called, is found in mineral veins, in the same manner as lead and copper, &c.

The strata which are generally the most productive of the metallic ores are lime-stones. Most species of whin-stones, of the indurated argillaceous mountain rocks, of which there are many varieties, appear in thick, thin, and middling strata, and some of these rocks are very hard, and others of middling hardness. These mountain rocks are of various colours, though mostly of some of the shades of grey. Many rich and valuable mines are found and worked in granite or moor-stone rocks: Such, for instance, are the lead mines of Strontian, in the Highlands of Scotland, and several mines in Cornwall, &c. These three orders or classes of rocks and strata are most commonly cut and intersected by mineral fissures, containing the greatest quantities of the metallic and other mineral ores.

In many countries, such as Derbyshire in England, the island of Islay in Scotland, &c. lime-stone is the most common repository of the precious and useful metals. In other countries, the most productive veins are found in granite rocks, as at Strontian above mentioned, where many of the veins are remarkably strong, bold, and roomy, in which exceeding good lead ore has been found in great quantities; and, in my opinion, few mining

fields in Scotland promise better success, if the best veins were properly explored with skill and perseverance.

But of all the classes of strata in which productive mineral veins abound, the indurated argillaceous mountain rocks are the most numerous and extensive. In Britain, all the rich and extensive mines of Leadhills and Wanlockhead, the mines of Tyndrum in the Highlands, of Machrimore in Galloway, and many others in Scotland, are found in some one or other of the species of this rock. Many of the mines of North Wales, almost all the numerous, rich, and extensive mines of Cardiganshire, and most of the other mines of South-Wales, are in these strata, and so likewise are great numbers of the mines of Yorkshire, Westmoreland, and many parts of the north and south of England.

I should in this place take some notice of the indications and external appearances of pipes and streaks, that is, of the pipe and flat veins. As the pipe veins only push downwards in a slanting direction, like an irregular pit or shaft, we are not to expect to find any longitudinal stretch or course in the external appearances of this sort of vein. This vein only bassets, or appears at the surface in a confined spot of only two or three feet, or of two or three yards diameter, and therefore we need not look for the indications at any considerable distance from that confined spot; only when the

basset or outburst of the pipe is situated upon a slope, or the ground has been much stirred by ploughing or otherwise, the mineral symptoms, whether hard or soft, may be scattered about much wider than the real diameter or compass of the basset of the vein, when it enters within the solid strata. If the basset of the pipe be situated upon a slope, the mineral symptoms will tend downwards, and therefore the basset of the vein, where it enters the solid strata, must be looked for higher up than where the symptoms are found; but if the site be upon level ground, the mouth of the pipe should be found about the centre of the mineral symptoms which appear, unless there be good reason to suppose that the shoads or indications have been all moved one way by some natural or artificial cause. The mineral symptoms or soils of the pipe are the same in quality as those of the rake which have been described.

The external symptoms and basset of the streak or flat dilated vein, have a longitudinal stretch or bearing as well as the rake vein. I have before noted and described this species of mineral vein, as being situated between the beds of particular strata, one particular stratum of the rock being the roof or upper side, and the next stratum below being the sole or under side of this species of vein. This vein does not cut in any direction across the strata, but, on the contrary, it stretches horizontally between the strata, and therefore it has exactly

the same longitudinal bearing, and the same spread or stretch every way, as the strata of the field in which the vein is found; and the flat vein is subject to all the accidents and irregularities of these strata, such as being thrown up and down off the ordinary level, stretch, and bearing of the strata, by slips and hitches, and of being partially cut off by dykes and gashes, which were described in the First Part of this work. But it may be observed, that miners have one consolation in meeting with these interruptions of regularity, which colliers are not favoured with, viz. every one of these are mineral veins of another description. The parallel, direct, and oblique slips, which throw the strata and dilated vein up or down off its former stretch and level, are each of them rake veins; and therefore, in meeting one of these in the course of working the dilated vein, a new chance of additional treasure presents itself, without the trouble or expence of looking for it. When a slip or rake vein is discovered in the progress of working a flat vein, it very often happens, that the slip vein contains good ore immediately when first touched; and in working this ore out of the slip vein, they come at the flat vein, where it floors and spreads out again upon the other side of the slip, whether it was thrown up or down by it.

The theory of the slip will, I hope, be now so well understood by my readers, as to enable them readily to comprehend, that when a miner is work-

ing forward in a flat vein upon one side of a slip with his face towards a particular point of the compass, and meets a down slip, if he were working upon the other side, with his face towards the opposite point of the compass, it would from thence be an up slip. The streak, flat, or dilated vein (for it is known among miners by all the three names), is frequently discovered by working downwards in the perpendicular mineral fissure, or slip vein. The flat vein appears in one or other of the sides as they go down in the perpendicular vein, and sometimes it contains ore immediately when discovered, and sometimes none at all, or very little of it. When good ore of sufficient workable thickness appears immediately, there is no difficulty. In that case they work away horizontally in good ore in the flat vein; but in some mining fields, the flat veins are overlooked, when they only contain mineral soils without ore, or a small quantity of ore where first discovered, which perhaps is not immediately worth working, because the miners in some countries do not understand the dilated flat veins, and therefore are neither moved by curiosity nor hope to look into them. I have, in some mining fields, seen five or six inches of good lead ore overlooked and passed by in working downwards in rake veins, without making the least trial upon the ore, particularly in the island of Islay, where I could not engage proper attention to the flat veins, because the miners

knew nothing about them; and as my visit there was but short, I had no opportunity of making them understand this species of vein. But in Derbyshire, and other parts of England, great attention is paid to all the streak veins. Indeed, much of the treasure of some mining fields, such as Derbyshire, is found in the streak veins; of course there is no danger of their being overlooked, whether rich or poor, for they know well by long experience, that this description of vein is fully as subject to checks and twitches, and other interruptions, as the perpendicular veins. It is very common for the flat vein to be squeezed thin upon one side or other of the perpendicular vein; and therefore, in a productive field, the flat vein should always be tried some fathoms in from the slip vein, until the influence of that squeeze or twitch be past over.

It was observed that dilated veins are most commonly found in the lime-stone country, that is, where strata of lime-stone are the prevailing rocks; however, they are not excluded from the hasle-whin and some other classes of strata. Whenever perpendicular fissures appear in the strata of lime-stone, there is always a chance, almost a certainty, of meeting with streaks, if the perpendicular veins be worked to any considerable depth. When the superficies of the rocks are bare and exposed to view, where a flat vein bassets out, the indications of the vein or the mineral soils advance forward

along the surface, in the same longitudinal line as the bearing of the strata; and, therefore, when any part of the basset or outbursting of a streak is discovered, if the trending of the strata in that place be known, the proper method of trying the basset of the vein in different places is easy and simple, as this vein always continues between the two strata which are at first found immediately above and below it.

Where the basset or superficies of a streak is discovered, and you want to make some trial to see how it appears under cover, at some considerable depth or distance from the surface of the earth, you are not to expect that this vein is to dip down precipitately like the perpendicular fissure, unless the dip or declivity of the strata in that place be so precipitate as to stand near the vertical position. In trying this vein you must consider the disposition of the strata. If they approach to the horizontal position, so will the vein; and, on the contrary, if the strata hang with so great a slope as to be near the vertical position, the vein will dip with the same slope, and likewise in all degrees of medium slopes between the vertical and horizontal positions; and, therefore, when the position of the strata is known, you know exactly how to pursue a streak under cover, even with unskilful men, or where there is not a considerable body of ore, or other good soils, to lead them in a right direction.

CHAP. IX.

OF THE DIFFERENT SPECIES OF LEAD AND COPPER ORES.

In the present Chapter, it is proposed to give a description of the most common species of lead and copper ores.

I. There are three principal species of lead ore, which are easily distinguished from each other, viz. *cubical potter's ore*, the *fibrous*, or *longish-grained ores*, and the *granulated* or *steel ore*; and of these three there are many varieties.

1*st*, What is commonly called *potter's ore*, on account of its being used for glazing earthen ware, is found in greatest quantity of all the lead ores. Much of this species of ore is of a tesselated, cubical, or diced structure. Some of the varieties of this species of ore are composed of very small cubes, others of middle-sized, and some of pretty large cubes, even up to near an inch square, the cubes appearing of a laminated texture, and slightly adhering together, so as to be easily broken to pieces with a small blow; and when broken, the

ore appears very bright and glittering, and of a fine metallic blue colour.

Many of the varieties of this species of ore appear of a laminated and scaly structure, approaching to, but not of a regularly diced form; and of these some are composed of large broad scales. And, again, some of these laminated or scaly ores have no appearance of a cubical form; but the masses of ore appear partly of a waved structure, the scales being irregularly disposed and placed in various ways.

But it may be observed of the potter's ores, that, in general, a rich and plentiful vein produces ore of a regularly diced form, without much variety of structure; but when the vein is confined or irregular, or any way disturbed by checks, thick riders, or from bending or warping, the ore is generally found of an irregular texture; and if the vein be much contracted and irregular, the small quantity of ore which it yields will be found in less regular masses. But when the veins are free from these accidental irregularities, and open into wide cavities, producing rich bodies of ore, the ore then assumes a regular form and texture. All the potter's ores are extremely heavy, and they commonly yield a great produce of lead in smelting, but they seldom contain much silver.

2*d*, The fibrous lead ores. These frequently exhibit a longish grain or structure, sometimes approaching to a striated form or texture. I have

seen some of the varieties of this species exceeding bright and beautiful, and more of a whitish blue, or a silver colour, than the bright potter's ores, and many of them are remarkably rich in silver.

3d, The steel-ore, or steel-grained lead ore, is of an uniform and granulated texture, some of the varieties of which are composed of fine grains, appearing in the inside of the mass like fine steel when newly broken; some like coarser steel; and others appear like coarse iron. Much of the steel-grained lead ore is bright and sparkling in the inside of the masses, and of a fine blue or silver grey colour. Some of the varieties are of an iron grey; and others, still more dull in the inside, approach to a blackish grey. The steel ores are mostly very hard, the masses being frequently sonorous in some mine works, and they are generally rich in silver.

There are rich and durable mines of this species of ore in Cardiganshire in Wales, and many other parts of Britain. Many of the veins producing this sort of ore in Cardiganshire contain strong, regular, and extensive ribs of solid ore, some of which were wrought to great advantage; but several of these rich and valuable mines are now under water.

A great many veins in the neighbourhood of Darenvaur, Cwmsymlog, Cwmystwith, about the north and north-west corners of the county, and

in many other places, have produced great quantities of the richest lead ore in the island, at least the richest in silver. Many of these veins were opened and worked by the Romans, whose works were remarkable and singular, being all open cast, like a great ditch or gulph. They cut open the vein longitudinally, and formed wide gulphs in the course or bearing of the veins. I saw one of these gulphs at Darenvaur, where the fine steel-ore was very rich in silver, so large, deep, and long, as to begin upon one side, and reach quite through the summit of a considerable mountain; and this vast trench was so deep and wide as to be about seventy fathoms below the surface of the ground near the summit of the mountain; but they had worked none in the vein down in the level ground at the foot of the mountain, where I saw very rich modern works under level, upon a regular rib of steel ore, which was from a foot and a half to three feet wide in different parts of the vein, and remarkably rich in silver.

Great numbers of these veins have been worked in modern times, as deep as they could go, with such level mines as were easily obtained to drain the water; but as Cardiganshire is distant from the wealthy mining countries and mining companies, little or nothing to signify was done below level about forty years ago, when I was pretty well informed of the mineral history of that county;

and I was lately told that very little has been done below since that period.

When these rich veins are opened again, and well explored, valuable treasures will be found in most of the old soles below the levels, by which they were formerly worked, as well as new ground, in different places in the course or bearing of the veins. I have myself seen fine ribs of solid ore in that county from one to three feet thick and upwards, which are now lying under water; and I was then well informed of others which I did not see. But few of these rich mines can now be effectually opened without powerful machinery for drawing out the water.

As most of Cardiganshire is a hilly country, consisting rather of ridges of a moderate height, with narrow valleys between them, than of high mountains, rivulets and runs of water may be collected and led to proper places; and reservoirs may be made for keeping quantities of rain-water, for working powerful hydraulic machines in many places. In other situations, nothing would answer effectually excepting the steam-engine; but there is as yet no pit-coal discovered in the county, or near it, and the expence of bringing coals by sea cannot be supported by any common produce.

The country to the northward, north east, and eastward of Darenvaur, abounds in peat bogs, and some veins bearing lead ore have been discovered,

but not explored, in the middle of some of these peat-mosses. Where good ore is found, and water cannot be had, or cannot be properly applied, steam engines may be worked with good peats well prepared. In preparing peats for the engine, the upper parts of the moss must be cut off and thrown aside; and nothing but the black heavy peat should be employed. This black moss should be cut into small peats early in the spring, in order to have the peats in good condition before the heavy rains come on, the dry weather of summer in that country being only in the early months. The heavy black peat, which is a close and solid substance, cannot be thoroughly and perfectly dried in one year; but when two years old, and well prepared and kept dry, it makes a strong, clear, and durable fire, little inferior to good coal. Steam engines, particularly those of an improved construction, which require less fuel, may be effectually worked with the black peat, without any material alteration in the construction of the machine, excepting that the furnace may be a little wider than for pit coals.

Besides the above-mentioned blue lead ores, there are other species of different colours, such as white, yellow, green, brown, and a yellowish brown colour, &c. But these several species are scarce, and of little consequence, as they are but seldom found in such quantities as to constitute

rich veins worth working, and therefore a particular description of them would be useless.

These several sorts of lead ore can only be distinguished from other mineral substances by a skilful eye, and even the most experienced are not always certain of them without proper trials.

II. COPPER ores are found in Britain of almost all colours and shades, such as black, red, brown, yellow, green, blue, grey, with all the mixtures and shades of these colours; and the ores of copper assuming such a variety of colour and appearance, make many of them difficult to be known, as some of them resemble at first sight many other fossil substances. Many of them, which are more obvious, have a bright metallic apppearance in the inside of the masses; and it may be observed of most of these ores, that they have always a mineral appearance, which will distinguish them; and when masses or shoads are found which are doubtful, there is a short and ready way of trying this metal, to know with certainty whether the doubtful mass contains any copper or not: viz. put a little aquafortis with a feather upon the mineral mass; let it act upon it for a minute or less, and then touch the part with a knife, a key, or any other polished iron; if it be copper ore, a thin plate or scale of pure copper in its native colour will appear upon the iron. The aquafortis dissolves part of the copper out of the ore or stony mass in which

it is concealed; but when the iron comes in contact, it precipitates the copper upon its surface. But it should be remarked, that if the copper be mixed with, or contained in any species of gypsum, vitriolic pyrites, or other mineral substance containing much of the vitriolic acid, the aquafortis will not act upon the copper so as to produce the real metal in this experiment. In this case, fire is necessary to prove the existence of copper in the doubtful specimens.

Many species and varieties of copper ore are found and worked in this island, some of which I will describe in a plain and familiar way, so as to convey a distinct idea of the several sorts when discovered. Some species of copper ore are of one uniform colour, and other species contain two or more colours in the same mass of ore.

1*st*, Native copper, commonly called virgin copper, resembles the metal itself in colour and quality, as it may be either cut or hammered when first discovered or dug out of the earth.

2*d*, Grey copper ore is a common species found in Britain. Some of the grey ores are of a granulated texture, or steel-grained, tolerably bright in the inside, considerably ponderous, and of a silver grey, a stone grey, or iron grey colour. But all the grey copper ores are not of a granulated structure; some of them are smooth and uniform in the inside; and when the ore is bright, it exhibits a glossy appearance, and this sort is frequently call-

ed *glass copper*, or *vitreous copper ore*. Many varieties of the vitreous ores of this colour discover, internally, less or more of a yellow or of a brown mixture with grey; and, again, all the varieties of the grey ores are not of a bright metallic appearance, some of them being more dull and tarnished. This species commonly yields a good produce in smelting, and some of the varieties are often found to be rich in silver.

3d, Red copper ore. Some varieties of this species are of a clear bright red, and of a smooth uniform texture, called vitreous red copper ore; but the most common sorts are of a darker red, approaching to a brownish red colour.

The masses of this kind are sometimes sonorous, generally ponderous, and some of the varieties are more like the melted metal than any other species of mineralized copper ore. Some of the red copper ores are of a granulated, and others of a solid uniform texture. The varieties, which are of the finest red colours, are generally bright and glossy in the inside; but some of those which are of a brownish red, have a more dull appearance; however, most of the red ores yield a good produce in smelting.

4th, Yellow copper ore is the most common species found in Britain. There are a great many varieties of yellow copper ore, most of which are very bright and beautiful, of a glossy metallic appearance, and of the colour of polished brass. Some

of the best of the yellow copper ores approach to a laminated texture, and are smooth and shining in the inside. Some of the yellow copper ores are of a granulated or steel-grained texture, but most of the varieties are smooth and uniform in the inside, without any determinate grain. Many of the yellow copper ores differ but little in appearance from some of the brighter pyrites; it requires a skilful eye to distinguish the one from the other, and sometimes they cannot be distinguished without aquafortis, or some other mode of trial. But although yellow copper ore be the most common and the most beautiful, yet in general it is not the richest. Most of the varieties are the poorest in the produce of the furnace; but what they want in quality is made up in quantity, there being more rich and plentiful mines of this species in Britain than of any other colour. When yellow copper ore exhibits a tinge or efflorescence of green, it may generally be known as such by the young miner; but when it is of an unmixed yellow colour, it should be tried with aquafortis or otherwise, before the landed gentleman builds too much upon its value.

5*th*, Copper ore of a mixed colour, containing two or more colours in the same mass of ore. In some veins masses of copper ore are found of a pure unmixed green colour, and also of a blue colour. Some masses are purple, and others black, and of a liver brown colour, with little or no mix-

ture of other colours in the respective masses; but it more commonly happens that several of these colours are blended with yellow, and may be distinctly seen in the same individual mass of ore. Masses of copper ore, or of supposed copper ore, of a pure unmixed green, blue, purple, or liver brown colour, and of a smooth uniform texture, require to be tried with aquafortis, as well as the pyritical or marcasitical yellow copper ores, before it be determined that they really are copper; because very many stones and pyrites so nearly resemble these in colour, texture, and the general appearance of the mass, that sometimes they cannot be certainly distinguished without trial; however, the doubt is soon cleared up with a drop of aquafortis, and a key or knife, as directed above, excepting in the case of the mass of ore being mixed with a gypseous matter, or being saturated with the vitriolic acid, in which case the aquafortis will not dissolve the copper so as to produce a thin plate of it upon the polished iron; and therefore, when the mass of ore has a strong metallic or mineral appearance, and yields no copper with the aquafortis, it will be prudent to have it tried by a proper chemical process.

The copper in many veins is composed of yellow and green; in other veins the ore is chiefly of the yellow and brown colours blended together. In some veins we find a mixture of yellow, brown, and green; in others a mixture of yellow, black,

and brown; and in some veins there is a mixture of yellow, purple, and of all the glowing colours of the rainbow and peacock's tail. In short, copper ores are found of all colours, and of all the shades and tinges of those colours; and many of those colours are often mixed and blended in the same vein, and several of them even in the same individual mass of ore, which makes a just and proper description of some of the copper ores a difficult task.

Some of these mixed copper ores are of a granulated texture, or approach to a steel grain; but most of the varieties are solid, hard, and firm, and of an uniform texture. Some of these are dull and strong like, and many of them appear of various degrees of beauty and metallic brightness.

Copper ore is often decomposed and dissolved by corroding waters passing over it; and the particles thus dissolved are often carried away by water, and lodged at different distances from the veins. This weathered or dissolved copper is found in many places in the state of an ochre or of a loose powder.

This powder is commonly of a green or of a blue colour, and is called mountain green and mountain blue, some of which appear of a beautiful bright green and blue colour, and others are of a more dull and earthy appearance. Some of the ochreous copper ores are indurated, and others are more loose and friable; however, all these

may soon be ascertained with a little aquafortis. In this experiment, the friable ochreous and the powdery samples must be put into a drinking glass, with some aquafortis; and after standing for a short time, touch the liquid with a key or a knife, and a thin plate of real copper will appear on the iron, if the matter so tried contain that metal.

Copper found in the state of an ochre or of a powder is commonly mixed with calcareous matter, and effervesces in the aquafortis in the same manner as lime-stone and other calcareous substances, and some copper ore found in veins likewise effervesces with aquafortis; but the calcareous mixture does not hinder any of these samples to show the copper upon the iron in the experiment with aquafortis.

The several sorts of copper ore cursorily pointed at under these few heads, especially the last article, might be subdivided into a number of distinct species and varieties. But as my aim is to point out such marks and characters as shall make these ores known, and as may distinguish them from other fossil bodies of nearly the same colours and appearance, I am no way concerned about a formal mode of classing them.

The mineral veins which contain the various species of copper ore, are exactly of the same description as the lead veins, and the various unmetallic mineral substances, hard and soft, contained

in those veins, are the same which have been fully described above, and therefore a farther repetition would be useless. However, it may be observed, that in soft veins containing *chun* and mineral clays, we need not look for copper in the white and whitish friable clay described above, which frequently contains particles, and sometimes seems to be a quantity of native ceruss. There seems to be a quantity of native ceruss mixed with this mineral soil, which perhaps has been produced by acid corroding waters dissolving part of the lead ore, which produces the native ceruss that is mixed with this clay, and which coats or covers all the shoads, and all other masses of lead ore that are covered with a white coat, efflorescence, or rust.

The veins which contain copper and lead ores, as I observed above, are the same, and the various mineral bodies which accompany both these ores are also very near the same; and to save unnecessary repetition, it is also proper to observe, that the various kinds of copper ore are found in hard and soft veins, exactly in the same manner as the various species of lead ore; and therefore, when a mineral vein is discovered, in which no lead ore is found, it should be carefully examined for copper.

As all mineral substances in the basset, outburst, or surface of a hard vein are sometimes so tarnish-

ed and discoloured as to conceal their native hue and appearance, I before advised, that the surface of every substance within the sides of a hard vein should be broken or scratched; and if no lead, or but a very small quantity be found in it, it should then be carefully examined for copper. Copper ore in a hard vein may be either red, black, blue, green, yellow, grey, and brown, or of the various shades and various mixtures of these colours. Most of the copper ores of the simple colours, and of their shades and varieties, have a metallic appearance, with various degrees of mixtures sufficient to distinguish them from mere stones or other mineral substances of the same colour, especially in very hard veins. However, some varieties of these ores may be so dull and tarnished as not to be easily distinguished; in which case, aquafortis should be used, when fossils resembling any sort of copper ore are found in such a vein. It commonly happens, that some little verdigrease, or a fine green rust or efflorescence, appears upon the face of copper ore exposed to the external air in the surface of veins, and likewise upon the outside or surface of loose masses of copper ore, which have long been exposed upon the surface of the earth: However, if no verdigrease or fine green rust should appear, the various colours and appearances of the copper ores have been so particularly described as to point them out to an attentive observer, independent of the

verdigrease, which, indeed, is always an indication of the presence of copper.

Copper ore may be, and often is found upon the surface of the earth in shoads and floats, in the the same manner as lead ore; and therefore, when vein-stones, spars, &c. are found scattered upon the surface, they should be carefully examined, to see if they contain any copper in specks or flowers. Masses and small bits of copper ore which have been forced off the basset of a vein, and lie scattered upon the surface of the ground, generally show some little verdigrease; and when they do not, the ore has much the same appearance as described above, only a little more dull and tarnished than samples of the same ore newly broken, but the tarnishing is only upon the outside of the masses; but however dull and tarnished such masses may appear, they have generally a mineral appearance and character, which distinguishes them to an observing eye from common stones; and therefore, when spars, vein-stones, &c. are seen, every hard substance in such a place should be broken, to see how they appear in the inside.

CHAP. X.

OF COPPER MINES IN SCOTLAND,

Copper ore is found in all the descriptions of soft mineral veins, in the same manner as lead ore, and the copper is accompanied in these veins by most of the soft mineral soils which accompany lead, excepting the white friable clay, which seems peculiar to lead. But of all the soft mineral soils found in veins, the blackish and all the shades of brown *chun*, or mother, is the most promising for copper. It has been noted before, that chun, also called *ghurr*, is a soft, lax, friable soil, which is found in the cavities of mineral veins, and generally has the appearance of snuff when the vein is dry.

When a vein is found, and opened a little, containing this sort of soft soil, if no lead be found in it, then it ought to be carefully examined for copper. Let every hard substance found in the vein, whether it be mixed and buried in the soft substance, or adhering to the sides, from the size of a small pea, and upwards, be broken, to see if any copper appear, which in such veins is commonly

so tarnished as to conceal its real colour and metallic appearance, which, however, will be discovered when either small or great masses containing copper are broken. But if no masses of good copper be found, and no specks or threads of copper be discovered in breaking the hard substances of the vein, then let some of the chun be put into a glass with aquafortis, and after standing a little, touch the liquor with clear iron; and if any copper appear, it may be concluded that it is a copper vein, and farther trials should be made by sinking down in it, even to a considerable depth, there being little doubt of finding much copper in such a vein, if you go farther down in it.

Copper mines have been worked for a long time in many parts of England, to the great emolument of the public, and of the several districts where this metal is found; but mines of copper have not hitherto made any figure in Scotland. The trials for that metal have neither been numerous nor very successful, perhaps for want of skill and perseverance. But however that may be, as it is probable that more attention will be paid to that metal hereafter in this country, I will point out some places where I have seen copper ore, and appearances of good copper mines in Scotland, which may be useful to posterity.

A great many mineral veins appear in the cliffs of the sea, all round the coast of Caithness, in the

north of Scotland, in some of which I have seen lead, and in others copper ore.

Many of those veins are hollowed by the waves of the sea washing out the softer mineral soils. There are several fine regular rake veins trending towards the north and south, and others towards an east and west direction, near the old ruinous castle of Old Wick in Caithness. These veins intersect one another at right angles, and in some of them I found pretty good copper ore.

The veins at Old Wick are remarkably good and promising, and regularly open between the sides, containing some copper ore even at the surface, with various other good mineral soils both hard and soft. I just touched the surface of two of the north and south veins at Old Wick, which could not be called a trial. One of the places was in the cliff of the sea, about half way down from the summit, in a strong bold vein, containing some copper ore; but as most of the mineral soils in this vein were hard, there was but very little done in it. The other vein was also seen in the cliff, but it was searched for and found by a little trench upon the plain ground above, at some distance from the face of the cliff. This vein was found open and good immediately below the upper soil, containing spar and vein-stone, and a blackish brown chun, or soft mineral soil, with some copper ore, at the very surface; and if I remember

well, there was not above a yard sunk down in the vein, just to see how it appeared.

The copper was found in small masses in the chun, and mixed or blended through all the veinstones and spar. The copper ore at Old Wick was mostly of a yellow and a brown colour, and frequently a mixture of yellow, brown, and green. It did not appear to be very rich in quality; but, perhaps, that is not ultimately against it,—for it may be remarked, that in Cornwall, and other places where they have the richest and most durable copper mines, the ore is generally poor in quality, which defect is compensated by the great quantity produced; and as far as I can judge from appearances, Old Wick promises to be a productive copper mine, when the best veins shall be opened and effectually explored.

The best copper ore that I ever saw, and perhaps the best that has been seen in Britain, is found at Kissern in the West Highlands of Scotland. This remarkably rich ore is of a reddish grey colour. It is uncommonly ponderous for copper ore, and the best masses of it are sonorous, and ring like the melted metal. This fine ore is found in a rake vein, or perpendicular mineral fissure, which crosses a middle-sized hill of fine limestone, within a mile of an inlet of the sea called Loch Kissern, upon the west coast of Ross-shire. Superficial trials have been made at Kissern, and some tons of copper raised at different

periods. The ore is found in nests or small openings in the vein, with short intervals between them, but they have never yet sunk to any depth in it. I am of opinion that Kissern deserves to be explored more effectually by proper trials. There is the highest chance in its favour, not only of this vein and other perpendicular fissures opening wider and more regularly at proper depths, and producing good bodies of ore; but there is also a probability of discovering dilated veins as they work down in the rake veins.

Flat dilated veins are commonly found in all limestone mining fields, and they would probably be met with at Kissern, were the perpendicular veins worked deep enough. When I was at Kissern, I saw the basset of a flat vein in the limestone measures, containing iron ore at the surface, a common circumstance in other copper mines. The rake vein, out of which the copper was raised, opens and closes, or checks again, at short intervals near the surface. The ore was found in every small opening of the vein, and the quantity found was always in proportion to the size and length of the open space; and when these openings closed or checked as they worked forward horizontally in the vein, the copper was cut off until they came to another opening, which was commonly at the end of two or three feet, or of two or three yards at most, when they were sure to find more copper. A shaft put down in the vein where the

best and most copper was found, to the depth of twenty or twenty-five fathoms, and a horizontal mine driven likewise in the vein from the bottom of the shaft, a considerable number of fathoms towards the height of the hill, might be productive of great discoveries. At any event, the copper which would be raised in going down and driving in the vein, would probably defray the expence of the operation. This may be done at a moderate expence, with a small horse-gin or whimsy, instead of a windlass, for drawing the water and work in sinking.

Among the prodigious number of lead veins which are seen in the island of Islay, there are a few regular good veins containing copper ore, upon which trials to a small depth have been made, and several tons of pretty good copper ore were raised out of them. The copper of Islay is mostly of the yellow, brown, and green colours mixed together, and of a close grain or texture; but most of the copper of Islay is mixed with blue lead ore, which is a great detriment to the copper.

The Ochil Hills, in the vicinity of Stirling, are famous for producing various kinds of good metallic ores in several places, such as silver, lead, cobalt, &c.; and among the rest, copper ore has been found in several parts of those mountains. I saw some very good regular perpendicular veins bearing copper ore, near the bridge of Allan, which have been worked, and a great deal of cop-

per raised at different periods. The copper of this mining field is good in quality. The ores are yellow, green, and grey; and the yellow, which is very bright, and of a laminated structure, was the finest yellow copper I ever saw. From my own observations, joined with the information of skilful miners, I am of opinion, that the copper mines at the bridge of Allan were rashly thrown up and stopped about twenty years ago, at a time when they had good copper in several foreheads, and still better in some of the soles, and, as I thought, in sufficient quantity to be worked with profit. But there being no furnaces and other apparatus for preparing and smelting the metal in Scotland, is a great detriment to the success of copper mines in this country. This mining field, however, promises a rich and plentiful produce of copper, if conducted with skill, spirit, and frugality.

There have been trials made, and grey, yellow, and greenish brown copper ores found at Currie, in the county of Edinburgh. The copper found at Currie was exceeding rich, of a bright grey colour, of a granulated texture, remarkably heavy, and very pure; and from its appearance I imagine it contained some silver. This fine ore was found in limestone; but I do not now remember whether the copper was found in a regular vein, or in nests in the lime rock. I also saw at Currie a great many small strings of copper scattered

in the superficies of the rock in several places, upon which superficial trials have been made at different periods. I imagine that they have paid too much attention to those vague appearances, because they saw some little copper, and neglected some real mineral veins, because they did not carry ore immediately at the surface.

There are appearances of other copper mines in several parts of Scotland, which I have not seen; and some that I have seen I do not so distinctly remember as to be able to give a just account of them.

In the parish of Colvend, in Galloway, there are great numbers of mineral veins, in which several species and varieties of copper ores have been found. Many of these veins appear in the rocky cliffs of the sea, upon the north side of the Solway Frith, which are high and precipitous. Several of the perpendicular veins containing copper in this field are so narrow and close at the surface of the ground, upon the summit of the rocky cliffs, that they could hardly be known above for mineral fissures, if they were not seen to open gradually wider and wider as they cut the strata asunder down the face of the cliff; but many of them open asunder to three or four feet wide, before they are half way down from the summit to the beach, where they reach to six or eight feet wide. Some of these veins are hollowed a considerable way into the hill by the conti-

nual beating of the waves, which wash or gradually wear the mineral soil out of the veins.

When I was in that part of the country I examined these rocks; and the result of my search was, that I found copper ore in the cliffs along shore in more than twenty veins. In a year or two after the first discovery, a company tried several of those veins, and some tons of copper were raised and sold; but whether the company and their servants had not sufficient skill in copper mines, or that they made some superficial trials in too many places where a little copper appeared, but did not push far enough into the best veins with sufficient spirit and perseverance, or that the ore was found in too small quantity to be worked with profit, or whatever was the cause, the work was thrown up, after making a great number of trifling trials, although some copper was found in most of them. From what I saw and know of the matter, as I sometimes passed that way, my opinion is, that they tried too may places which deserved no trial at all, and of consequence they soon found too much money out, and but little coming in, which discouraged them; whereas, had they concerted and steadily followed a proper plan, and pushed their trials effectually in two or three of the most promising veins containing copper ore, it is highly probable that their success would have been quite different, and that this

would have proved one of the greatest and best copper mines in Europe.

A great variety of copper ores appears in this extensive mining field. The principal species are the yellow, green, and brown, with a great variety of mixtures of these colours, some of which are tinged with all the beauties of the rainbow and peacock's tail; but these gaudy ores are generally in hard poor veins, which do not promise much success, at least near the surface. In the more open veins, containing soft mineral soils and spar, &c. the yellow ore mixed with green and brown colours are generally prevalent. There were ribs of solid ore in some of these veins, when the trials were given up; and in one or two of the best veins the rib was up to four or five inches, of a brownish yellow copper, mixed with green. I am persuaded that the ore in some of those veins would pay for working, as it now stands, if managed with spirit, skill, and frugality; and as the veins are good, and trend into a range of mountains which have a gradual rise or acclivity from the shore, until they ascend to a great height, there is the greatest probability of success, by driving horizontal mines or galleries in the veins from the shore, towards the mountains, in which veins there is middling good ore to begin upon, which would pay for the mine or gallery; and as most or all of these veins open gradually downwards, it might be prudent to sink down below the level of the

sea in one or more of the veins which produce the best ore and other mineral soils. In short, this is a noble mining field for an able, skilful, prudent company to engage in; and I am persuaded that, some time or other, when the best veins shall be properly opened and pursued, it will prove one of the best and most extensive copper mining fields in Britain.

CHAP. XI.

OF THE ORES AND MINES OF IRON.

The next metallic ore I shall take notice of is iron. In these cursory observations, concerning the metallic ores, I follow no particular method; my chief object is to point out the extent and riches of our British mines, and their importance to our manufactures and commerce. Our lead and copper mines have long been worked on a great scale, and to great advantage, and it is yet very practicable to increase them. Our iron mines and iron furnaces have begun to make a figure of late years, and I hope they will increase in some proportion to their great national consequence.

Of all the mineral ores found in the superficies of the globe, iron is of the greatest importance for

all the purposes of society; and therefore it should be reckoned the most precious, as it is the most useful of all metals. Iron is either necessary or applicable to most of the great and important uses of metal. Some of its properties, indeed, are against it for several domestic and ornamental purposes; but where the great and necessary uses of metal are wanted, for strength, durability, fine edge and point, iron is, without comparison, the most useful and the most valuable metal in the world; and, like the other common bounties of Nature, the general abundance of iron is equal to its great utility. The other metals have also their value and importance in various ornamental and useful purposes of life, and they are of great consequence to our British manufactures and commerce.

Unless it be the first great expence which is requisite for erecting iron works, I am at a loss for the reason why we have so few blomaries in the island of Britain; and why we were so long, in Scotland especially, before we began to extend this valuable manufacture of our own produce, which is of such vast national importance. It is said that a million of good hard cash is annually carried out of the nation for iron, which goes into the coffers of cold friends and commercial enemies. It should be the fervent wish of all the real friends of our national prosperity, that the iron works of Britain were so much increased, as at least to keep our dry cash at home; and if we im-

ported any iron at all, that it should be in exchange for British manufactures; and I am persuaded that the means of such an increase are abundant.

Iron works in Scotland, for manufacturing the produce of the country, are but of very late establishment; but to my certain knowledge, the materials of numerous iron works in this country are abundant and good. I will not pretend to reason upon the policy of national bounties to encourage the increase of these public works; but it appears to me abundantly evident, that bounties and premiums, wisely disposed of in this way, would prove a national advantage, by employing a great additional number of hands in preparing and manufacturing the produce of our iron mines, and in keeping at home a million of cash annually.

Iron, in its fossil state, is of two sorts, viz. iron ore and iron stone. Iron ore, properly so called, is found in all the several species of mineral veins described above, and also upon the surface of the earth, in a concreted state, which is called *bog-ore*; and iron-stone is found in thin but regular strata in the coal-fields and others, and in glebes and nodules of various sizes, blended in argillaceous strata likewise of the coal-fields. Several species of iron-stone, such as reddle, and slaty or shivery iron-stone or ore, are found in regular continuous strata among the strata of the moun-

tain rocks, and it is found in indurated rocks in many places.

There are several species of iron ore, such as, 1*st*, *Blood-stone*; 2*d*, *Kidney ore*; 3*d*, *Grey iron ore*; 4*th*, *Bog ore*, &c. and of each of these there are many varieties.

1*st*, The *hæmatites*, or *blood-stones*, are reckoned among the richest of the iron ores. They are either of a dark brown, a reddish brown, or of a grey colour, remarkably heavy, and generally of a radiated structure. The reddish and brown sorts are commonly of a smooth uniform texture; but the grey are frequently granulated, some of which are of a dark grey colour and dull appearance, and other varieties are of a light grey and of a bright metallic appearance.

The masses of these sorts are strongly marked being of a striated and radiated form and texture; the radii very distinct, and diverging every way from a common centre, and they are generally mixed with a whitish or flesh-coloured iron spar. Many varieties of the blood-stones are very hard, as well as the iron spar which accompanies them.

2*d*, *Kidney ore* is found in small masses blended in a red, staining, soft clay or earth, called *smit*, which is also an iron ore. The solid masses which are mixed in this red clay are remarkably heavy, and of a blackish brown, or dark grey colour; they are either roundish or kidney shaped, and of

a crustated structure, the small masses being formed of concentric crusts or folds like an onion, though in some varieties the small masses of ore are of a more solid structure, without the appearance of different folds or crusts. The most profitable iron mines in Britain produce this species of ore.

3*d*, *Grey iron ore*, of which there are many varieties, most of them pretty hard and heavy, and sometimes of a dull blue, but generally of various shades of an iron grey colour. Some varieties of the grey iron ores are of a granulated texture, and composed, some of coarse grains, resembling coarse iron when broken, and others of finer grains, resembling the steel-grained lead ores; and some of these are of a blackish or dark grey, and others of a bright grey colour, resembling some of the granulated lead ores. Again, some varieties of the grey ores are of a cubical or diced structure, and others are scaly, and these are composed of larger and smaller cubes, and of larger and smaller scales, in the same manner as the diced and scaly lead ores, which many of these resemble, only that they are of a duller blue, of an iron grey colour.

But I will not pursue this description, which is not very necessary, the iron ores in general being pretty easily known and distinguished from all others, by their being accompanied with less or

more of a brownish red, or of a brighter red soft soil, which indelibly stains the hands; and therefore I will leave this description, and proceed to point out some of the many places in Scotland where I have seen appearances of good iron mines. It was only for the sake of communicating this local history, which may be of future use, that I said any thing at all about iron.

I have formerly seen appearances of iron ore in several places round the coasts, from the west side of St Andrews to Montrose; but it is so long ago, that I cannot now give any distinct account of the matter.

About seven or eight miles north of Montrose, in the neighbourhood of a fishing town, which I think is called John's-Haven, there are strong appearances of plenty of good iron ore, particularly near Mr Carnegie of Charlton's lime-works. The iron among these lime-works appears at first sight to be plenty and good; but my stay there was so short that I had no time to examine it minutely. It is easily distinguished by the strong, red staining softness which accompanies it. If this ore be found good, it is almost close to the sea.

There are also appearances of iron ore between the same lime-works and Stonehaven, and between Stonehaven and Aberdeen; but concerning these I can say nothing distinctly.

There are strong appearances of iron upon the coast, about the Ord of Caithness, and in many

places between the Ord and Wick, and to the northward of Wick.

The coast of Caithness is remarkable for pretty high rocky cliffs, in which great numbers of veins, or perpendicular mineral fissures, appear, many of which contain iron ore. I remember observing some of these near the old ruinous castle of Girnigo, and between Girnigo and the castle of Ackergill. These veins appeared to be bold and roomy, and to contain plenty of good iron ore, from the abundance of a bright red iron earth found in the surface of them; but I did not thoroughly examine circumstances, having no prospect then that iron ore would so soon become of consequence in Scotland.

There is great abundance of bog ore over all the low country of Caithness. In many places it almost covers the whole face of the ground to a considerable depth. It is easily known and distinguished by the friable constitution of its misshapen masses, by its external blackish and rusty colour, and by its internal blackish grey colour and granulated porous texture. It is always found loose upon the surface of the ground, in the same manner as float ore, without any connection with vein or stratum.

Iron ore has been wrought in the main island of Orkney, and shipped for use at Carron; concerning which I can say nothing farther, as I never saw it.

Good iron ore appears in the lime rocks of Kissern in Ross-shire, where the rich copper mentioned above was found. I did not traverse all the lime rocks at Kissern, but I saw fine iron in them in two different places, and of two different species. The first which I observed is grey iron ore, contained in a perpendicular fissure or rake vein, which appears distinctly in the side of a small rivulet near the road, upon the south side of the field in which the copper was found. This vein, if I remember well, is between two and three feet wide at the surface, and full of good grey iron ore. In the other place, the iron seems to be of the species called *kidney ore*, and it is contained in a flat or dilated vein in the limestone, and situated about a hundred yards or more westward from the copper vein. I saw not the least trial upon either of these two, but they appear to be very good. The site of them and of the copper is about a mile from the sea, or salt-water loch of Kissern.

I am persuaded that several of the Western Isles abound in iron ore, some of which I have seen in Cannay, &c. which I had not time to examine.

There appears plenty of good iron ore in several mineral veins in the south side of the mining island of Islay, part of which is found in the lime within the bounds of the lead-mining field, and part to the south of the field which abounds most

in lead ore. There are many appearances of iron along the coast of Islay, which I have only seen at a distance; but from what came under my eye, I am confident that Islay is an eligible place to search for a valuable iron mine, which would answer well for iron works upon the Clyde, in Airshire, or in any part of the west coast.

A strong appearance of a great quantity of iron is to be seen in the hills which are situated to the eastward of Girvan in Airshire; which appearance of iron stretches away longitudinally towards the north-east, as far as the parishes of New Cumnock and Muirkirk, which may be soon of great use to the new iron works lately erected at Muirkirk, and perhaps to others in the course of time, there being plenty of coal and coal-field iron-stone in the south-east parts of Airshire.

Iron mines appear in many places upon the sea-coast of Galloway, particularly in the parish of Colvend, both to the west and east of the copper mining field above mentioned, where many veins containing kidney ore and other species are to be found; several of which I have seen, but not examined.

The north-west side of the Ochil Hills abounds in iron, which I have seen in crossing those hills. It stretches longitudinally, but of what quality I do not know; however, it deserves to be ascertained, the site being convenient for the great quantities of excellent coal and iron-stone of the

coal-field found upon the banks of the Devon, a plentiful stream, and in the moors to the south of the Devon.

The iron ore or iron-stone at Noblehouse is pretty well known, being opened a little a few years ago by the proprietor, Sir William Montgomery of Magbyhill. This is not a vein, but a stratum of iron, which stretches longitudinally a considerable way towards the north-east and south-west, through the lands of Magbyhill, La Mancha, and others. This stratum of iron is of considerable thickness, being above twenty feet across the stratum where it was opened at the surface near Noblehouse. It is a slaty or shivery iron ore, or iron-stone, of a reddish brown colour, and smooth uniform texture in the inside of the masses when broken, and mixed with staining iron earth of the same colour. When I saw this iron mine, I thought the ore should have been very rich, but was told that it only produced about twenty-five or thirty *per cent.* at most upon trial; however, as they only dug the surface of the stratum, which must be mixed with surface-earth carried down by rains into the iron ore for ages, I imagine it should be richer if worked down to a proper depth. I am persuaded that this will become of great value in the course of time, as the extensive moors to the north of it abound in coal and coal-field iron-stone, and the situation only sixteen miles from Edin-

burgh, and convenient for the extensive inland countries to the south and west of it.

The best of all iron-stone, which is found in thin strata, and also in detached glebes and nodules in the argillaceous strata which accompany seams of coal, abounds in all parts of Scotland where any strata of coal have been discovered. I call this iron-stone of the coal-field, because it is always found in those argillaceous strata which attend coal, and which are very commonly the immediate roof of coal; and therefore, it is customary to rummage the coal wastes for this sort of iron-stone, from whence it is raised much cheaper than by digging it out of solid ground.

This species of iron-stone is found upon both sides of the Frith of Forth, from the east of Fife and opposite, all the way up to Stirling, a length of more than fifty miles, and in a great many places it is found quite down to the shore, and within flood-mark. Upon the north side of the Forth, the coal-field, and of course the iron-stone field, is generally about eight miles broad from the shore inland. The iron-stone in this extensive coal-field is very plenty and very good, and it is all entire, excepting a very little, which the Carron Company have picked near the shore, and a considerable quantity which they have taken from Pitfirran.

The inland coals at a distance from the shore are remarkably good and plenty in several parts

of Fife and Clackmannan shires; and as there is appearance of iron ore in the Ochil hills, this country may, in the course of time, become the site of extensive and valuable iron works.

The iron-stone upon the south side of the Forth is found as abundant and as good as upon the north side, with this addition, that in many places the coal and iron-stone field upon the south side is more than double the breadth of the other. The greatest part of this south field reaches from the banks of the Forth all the way to the south side of Airshire, which is more than six times the breadth of that upon the Fife side of the water.

The Midlothian coal and iron-stone field reaches from the south shore of the Forth, near twenty miles up the country towards the south-west; and it is of pretty equal breadth, being every where about twelve or thirteen miles across. The south-east side of this field consists of a range of horizontal strata, and the north-west side of vertical or greatly sloping strata, and both ranges abound in good coals and iron-stone. The flat, broad, or horizontal coals of this great field are of excellent quality, and remarkably plenty and cheap in the neighbourhoods of Ormiston, Cranston, Carington, and Temple; which districts also abound in good iron-stone; and therefore these are supposed to be good situations for iron works. There are also appearances of iron ore in the range of hills upon the south side of this coal-field.

In the range of vertical and greatly sloping strata, in the north-west side of the Midlothian coal-field, there is a great number of thick seams of excellent coal, and the strata of iron-stone are innumerable, besides a great quantity of nodules contained in thick beds of coal-till, and all apparently of excellent quality. The coals of this range, for eight or ten miles from the shore, sell at a good price, being carried to Edinburgh; but farther up the country they are of small value, and either not worked at all, or to a very limited extent; and therefore it is presumed, that the neighbourhoods of Auchindinny, Pennycuick, and Newhall, would be eligible situations for iron works, which can be supplied with excellent and cheap coals from the horizontal strata upon the south, and from the edge-seams upon the north side of the river Esk, and with abundance of iron-stone from both, part of which can be carted westward from the coal wastes of Loanhead and Gilmerton.

PART III.

OF THE NATURAL HISTORY OF THE PREVAILING STRATA, AND OF SOME OF THE PRINCIPAL PHENOMENA UPON THE SURFACE OF OUR GLOBE.

In surveying the surface of the globe, various phenomena present themselves, which surpass comprehension. In one place the rocks are disposed in regular strata, but in another place this beautiful regularity is interrupted, and nothing appears but disorder and confusion. In the other kingdoms of nature, an intelligent and successful spirit of inquiry has made great and wonderful progress; but we are still in a state of infancy with regard to mineral science. Many fine things, indeed, have been said upon this subject by confident theorists, and by fanciful philosophers, which are disproved by

observation and experience. It may, indeed, be held as a maxim, that extensive and satisfactory knowledge of this subject is not to be gained at home.

Our powers are weak, limited, and imperfect, and the subject is vast, comprehensive, and various; and therefore we cannot, in the retreats of philosophic retirement, bring it near enough to examine facts. If we wish to attain competent degrees of knowledge in the history of the mineral kingdom, we must survey its territories, we must follow the example of eminent proficients in other branches of natural history, who take a small portion of the subject of their inquiries at a time, and patiently examine its minute parts. I have in some measure followed this method in my history of the mineral kingdom; and as I have seen much, I shall state a considerable number of facts, drawn from my own observation and experience, for the instruction of the intelligent naturalist.

In the prosecution of this design, I shall observe the following method.

I. I WILL take a general view of the prevailing rocks and strata of this island, to see which of them are regularly stratified, and which are not, with the different degrees of stratification.

II. I WILL give the natural history of the stratification of our globe; of the bearing, slope, and

continuity of the regular strata; and of the fissures, chasms, slips, and other interruptions of that regularity.

III. I WILL examine part of the modern system of Count Buffon, &c. upon this subject, to see how it corresponds with the real structure of the superficies of our globe.

IV. I WILL treat of the natural history of mountains; of their structure and external phenomena.

V. I WILL examine the nature, size, figure, and quality of the larger grains and fragments which are found in the composition of our rocks and strata.

VI. I WILL select some particular strata for examination.

VII. I WILL offer a few observations concerning several other interesting subjects relating to the mineral kingdom.

These will form the topics of the following Chapters.

CHAP. I.

OF THE PREVAILING ROCKS OF BRITAIN, AND OF THE DEGREES OF THEIR STRATIFICATION.

I BEGIN by taking a general view of the prevailing rocks and strata of this island, to see which of them are regularly stratified, and which of them are not, with the different degrees of stratification.

I. I WILL first treat of the whinny and the argillaceous regularly stratified mountain rock, for no other reason but because there is more of it found in Scotland than any other kinds. The regularly stratified mountain rock may be divided into several species or varieties; as,

1. SUCH as is found in regular strata of middling thickness, strong, hard and heavy, commonly of a blackish grey colour. This stone is generally mixed with grains and particles of quartz, schorl, and iron, though frequently in particles so small, and so well mixed, as not to be visible to the naked eye. This variety is common in many parts of Scotland, in high and low lands, and is called *whin-stone*; but though regularly stratified, it is fre-

quently too hard and strong to be quarried for ruble-stones.

2. A SORT thinner bedded than the former, and seldom quite so hard; nevertheless, this variety is much of the same quality and colour; it is always regularly stratified, and commonly makes excellent ruble-stone for building. There is a curious variety of this stone found in the Highlands, and in several places in the north and south of Scotland, which may be called streaked or striped, each stratum of the rock being composed of several stripes of different colours, commonly white and black alternately, and frequently white and grey. Some of these streaks are not above the eighth part of an inch thick, and some are up to half an inch; but what is most remarkable in this stone is, that the thinnest of these streaks spread out the whole breadth of the stratum of stone regularly, so that, when you see a clean section of one of these stones broken across the bed of the strata, these variegations have much the appearance of fine striped stuffs.

3. *Hastle-whin*, or the indurated hastle-coloured argillaceous strata, of which there are considerable varieties; some of which have a fine close uniform texture, thin bedded, and often containing distinct impressions of various small plants between the laminæ or folds of the strata, and some

are of a more coarse and gritty texture; and the coarser sorts are generally found in thicker beds than the former.

4. Ash-coloured argillaceous mountain rock; some varieties of which are found harder and stronger than the hastle, and some more soft and tender. This species or variety of the mountain rock is very common in many parts of the high and low lands of Scotland; and it is generally disposed in thin and very regular strata.

5. Argillaceous strata of a purple and a purplish brown colour, of which there is a great variety; some of it being indurated to a considerable degree; but much of it soft and tender, of a marly texture, and apt to decompose when exposed to the air and weather. With this species or variety may be ranked all the brown and reddish brown argillaceous strata; but as they differ little in quality and texture, it would be useless to enumerate them all. They are generally regularly stratified.

6. Blue, purple, ash-coloured, and grey strata, of a fine smooth grain and laminated structure. The slate rocks are generally composed of fine particles, and these particles are as finely united. These rocks are stratified in the highest degree of perfection; and from the finely laminated texture

of the strata, they cleave so thin and regular as to make a light, durable, and elegant covering for houses. The fine blue slate of Easdale and Ballachylish in the Highlands of Scotland, is well known, as well as the blue slate of Stobo in Tweeddale; but there is a fine purple slate rock near Tombay, above Callender in Monteith, which is less known. This is a plentiful slate rock of excellent quality, and of a rich purple colour; but only a little of the loose and shattery surface of this rock has been worked.

7. PLATE and schistus, of which there is a great variety in many of our mountains and valleys. Some varieties of the schists or shivers are of the same colour and quality as the slates, the only distinguishable difference being in the stratification. The strata of slate are found regular and finely laminated; but the plates and shivers frequently exhibit nothing but a confused irregular mass; some of it as if it were half stratified, and a great deal of it without the least appearance of strata; and when there is an approach to regular stratification, it is to be observed that the stone itself approaches to the quality of slate. I observed before, that there is more of the argillaceous than of any other species of rock in this country; and among the varieties of it, the schistus is the only one that is not very regularly stratified.

There is a great variety of the schistus, both in

colour and texture, which is not stratified at all. Some of this is found in prodigious thick beds, of a friable texture, appearing like an indigested mass, frequently containing balls and irregular masses of highly indurated stones of various sizes and colours. Some of the schistus is of a laminated texture, separating into small thin scales and glazed masses of various sizes, all of them thin at the edges, with an oily or slippery smoothness to the sight and in handling. Again, some of the beds of schistus appear in a thick homogeneous formless mass, without any intermixture of balls or other hard masses, and some of it contains small masses of pyrites, quartz, &c.; the quartz sometimes appearing in discontinuous veins or ribs, and in misshapen masses of various sizes. This variety of the schistus is frequently pretty hard; and where it is mixed with quartz, it is not uncommon to find some masses of lead ore in it. I have frequently seen small quantities of lead ore in rocks of schistus in the Highlands of Scotland, &c. but I never saw it come to any thing upon trial.

II. GRANITE rocks. The granite is a strong, hard, and heavy stone, of an irregular texture, composed of grains and fragments of various sizes, quality, and colour; and of this there are several species, such as,

1. Elegant reddish granite of a crystallized tex-

ture, in which the pale rose and the yellowish colours are finely mixed and shaded. The mountains of Ben Nevis in the Highlands of Scotland are chiefly composed of this stone, and it is found in great abundance in many other parts of Scotland; but I never saw this variety exhibit the least appearance of stratification.

2. FINE reddish granite, in which it may rather be said, that the same colours are blended together than spread out with such finely shaded tints as the former. I have not seen this variety of the granite stratified; on the contrary, both these exhibit such a degree of uniform regularity, that in some places there is no difference between a stone and a mountain, excepting only in magnitude, as many mountains of granite are nothing but one uniform mass throughout, in which not the least mark of a bed is to be seen, or hardly a crack or fissure, unless it be at the edge of some precipice or declivity. These two varieties of red granite are frequently met with in the Highlands and Lowlands of Scotland, in Galloway, and many other places. We often find large masses of talc in this second variety.

3. STRATIFIED reddish granite, resembling the second in colour and quality, but not always quite so pure or free from admixture of other stony matter of a different quality. This variety of granite

frequently contains fragments of talc. It is in pretty regular strata in the shires of Moray and Nairn, and other parts of Scotland.

4. WHITE and whitish granite, generally of a loose granulated texture, containing a great quantity of mica, or small-leaved talc, and the grains of quartz sometimes large and angular. This variety of granite is apt to weather and decompose, and part of it frequently dissolves, and the dissolution often falls to a sediment in lakes, so fine and light as rather to hang suspended in the middle, and near the bottom of the water, than to sink in it. I have found this substance in many places, where water had been accidentally drained off, resembling fine shell-marl, only much lighter. When thoroughly dry, it is the lightest fossil substance I ever handled; and when blanched with rain, it is as white as snow. This variety of granite is either not stratified, or exhibits thick irregular beds. It frequently contains a considerable quantity of talc, in masses and scales, too large to be called mica.

The sediment which is found in lakes, from the dissolution of the white granite, if perfectly free from ferruginous matter, is reckoned an excellent ingredient in the composition of fine porcelain. It is highly probable that this is the kaolin of the Chinese.

The fine porcelain ware of China, we are informed, is composed of two different substances, called by them *petuntse* and *kaolin*. The petuntse is a fine white vitrescible stone, compact and ponderous, and of considerable brightness when broken. The kaolin is a fine white earthy substance, not vitrifiable, at least in the common heat of a potter's furnace. The kaolin and petuntse, reduced to fine powder, are mixed together, formed into a paste, and moulded into all sorts of porcelain vessels.

After a good deal of inquiry, it appears to me, that the sediment which I have mentioned above, is the true kaolin; and that the fine glassy quartz, which is found in irregular masses, and in irregular discontinuous veins or ribs, in some of the rocks of schistus, is the true petuntse; and if this observation be really true, it deserves to be remarked, that Scotland is as well furnished with the best materials for making fine porcelain as most countries in the world. The species of quartz which I suppose to be petuntse, is of a uniform glassy texture, semitransparent, and of a pure snowy whiteness. A broken piece of this stone, and a newly broken piece of fine porcelain, are very like one another. These hints are of importance; and experiments should be made to ascertain, whether or not these fossils possess the real properties of the petuntse and kaolin.

If the island of Britain contain this valuable treasure, it ought not to lie buried for want of attention. There is a great quantity of petuntse, or pure white quartz, in many parts of Scotland, particularly in the north and Highlands. There is a considerable quantity of it upon the shore, and washed by the tide, between Banff and Cullen, generally in large masses in rocks of bluish schistus. There is also a considerable quantity of it in masses and discontinuous ribs, in rocks of blue schist, three or four miles north of Callender in Monteith, on the side of the high road which runs parallel to Lochleodnich.

The kaolin is perhaps as plenty in Scotland as the petuntse, there being many extensive lakes easily drained, which contain a considerable depth of it; and, moreover, it is to be found in many places that have been lakes, which are now laid dry by accident. There is a quantity of kaolin about a hundred yards below the public road, upon the south-side of a bridge about two miles south of the inn of Aviemore in the Highlands. It lies beneath a stratum of peat-bog, in a place which has been a lake, but is now drained by the river Spey cutting through one side of the mound which formed the lake. This is very fine and pure, excepting that some parts of it are a little discoloured by a light earthy sediment which lies above it. There is more than one stratum of the

kaolin in this place, and some of it is exceeding white, especially when blanched by the rain; and there is a white granite rock up the rivulet, at some distance above the bridge, the decomposition and dissolution of which are supposed to produce this sediment.

Several lakes in the Highlands of Scotland are nearly full of kaolin. In Stratherig in Inverness-shire, on the west side of the farm of Drimin, is a pretty long lake, which contains a considerable depth of kaolin. This lake may be drained at a moderate expence; and if I remember well, the granite rocks which surround it are pretty white and fine. It should be remarked, that if the kaolin originate from coloured granite, it is good for nothing, especially if it contain the least tinge of iron, because this discolours and spoils the beauty of the porcelain; but wherever white granite is found composed of quartz, feldspar, and mica, without any admixture of schorl, and especially of iron, the kaolin should be diligently sought after in that neighbourhood.

I have been informed that Loch Doon in Galloway contains a great quantity of kaolin. This lake was drained some years ago, in the view of laying dry the shell-marl it was supposed to contain, which, however, upon trial, turned out to be kaolin. The one substance may very easily be mistaken for the other, as at first sight they are both

very like; but they may be distinguished with certainty, by trying both with acids. Shell-marl effervesces strongly in weak vinegar, whereas pure kaolin will not effervesce at all in strong aqua-fortis.

5. GREY granite or moor-stone, so called in Cornwall, composed of black and white grains of various sizes. This stone is very common in many parts of this island. In some places it shows no marks of strata, and in others it is disposed in thick irregular beds, which are commonly broken transversely into huge masses of various sizes.

There is a great variety of the grey granite, both in colour and texture. Some varieties of it differ but little in appearance or quality from some species of the basalts; others are composed of almost equal quantities of black and white grains, about the size of small peas, whence it is called *peasy-whin* by many Scotch masons. The grey granite, in Galloway and other places, exhibits a longitudinal grain or texture, as if the component parts had been all moved one way by a gentle flow of water.

When the grey granite begins to weather or decompose, which it often does, we can then examine its component parts; and we find some of it contains pretty large grains of a cubic, a rhomboidal, and other figures, and some of them so

large as to deserve the appellation of fragments; the largest fragments are always of quartz or feldspar, and of talc.

6. Grey composite granite, the texture of which, when broken, looks as if composed of small fragments of various sizes and shapes. When this stone is polished, the grains or fragments being all fine, they appear as if they were set or inlaid in a fine water-coloured pellucid matter. This is a most beautiful stone.

7. There is in some parts of Britain an imperfect granite of a loose friable texture, which is apt to weather, decompose, and be reduced to gravel. There is a remarkable rock of this species near the Queensferry in Scotland, on the road to Edinburgh, which appears in irregular thick strata.

This rock produces excellent materials for the high roads, and seems to be chiefly composed of quartz, schorl, and some iron.

8. There is a single stratum of very curious composite granite a little to the west of Lossymouth, in the county of Moray in Scotland, of about six or eight feet thick. This singular stratum is composed chiefly of grains and fragments of various bright and elegant colours; most of the fragments are as large as peas and beans, and they

are all fine, hard, and semi pellucid; and it is very remarkable, that there is about an eighth part of good lead ore in the composition of this stone, of the species commonly called *potter's ore*; and it is also remarkable, that there is no other granite in that neighbourhood but this single stratum; all the strata above and below it being mostly a coarse, imperfect, grey sand-stone.

9. THERE is also in many parts of the north and Highlands, and in Galloway, an excellent species of grey granite, composed chiefly of red and black coloured grains. This is a fine, strong, and durable stone, very fit either for massy or for ornamental architecture *.

III. LIME-STONE, which may be divided into the following species:

1. THE grey, whitish, and pure white, regularly stratified, mountain lime-stones, of a granulated texture, broad-bedded and strong, much used for building bridges in the north and Highlands of Scotland. Some of this stone breaks like coarse iron, but more of it like a sugar loaf; and I have

* The rocks described by the Author under the name of *granite* or *moor-stone*, are denominated *greenstone (grunstein)* by the Germans.—EDITOR.

seen much of it in the Highlands as white as the Parian marble; and some of it composed of fine glittering spangles as large as the scales of fishes.

2. COARSE-LOOKING grey mountain lime-stone, of a granulated texture, hard and strong, and difficult to work, exhibiting in some places an unequal, in others a smooth and regular surface, and sometimes appearing on the sides of the mountains and lower moors, when the soil is washed away, like large sheets of dirty ice. In some places this stone appears regularly stratified, in other places it appears in one vast irregular bed, of very unequal thickness.

3. ASH-COLOURED mountain lime-stone, composed of very small grains or particles of a fine smooth uniform texture, when broken, resembling flint. I have seen, in several parts of the Highlands, hills of this stone; some of which exhibit regular strata, and in other places it appears in one great mass, like the granite rocks. In the island of Islay, and in the country of Assint in the Highlands, and several other places, this species of lime-stone exhibits an unequal rugged surface. These jaggs are sharp-pointed, very hard, and close to one another, and some of them a foot or a foot and a half long, which makes it both difficult and dangerous to walk upon this rock.

4. REGULARLY stratified lime-stone, found in the low countries, of which there is an endless variety of colours and textures, as grey, blue, black, &c.; and these are found of all degrees of hardness and purity, and resembling almost every other stone.

5. LIME-STONES accompanying the coal metals, and frequently the immediate roof of coal. Of these there is a great variety in quality, colour, and texture, and there is as great a variety in the degrees of purity, some of them being so debased with clay and other heterogeneous matter, that they are good for nothing, and others as rich and fine as any lime in the world. The lime-stones of the coal countries are always found in regular strata, and the strata of these stones are more regular in the line of bearing than any other species of them that have come under my notice.

I have seen many other lime-stones swell out in some places to a prodigious thickness, so as to cover a large extent of surface; but this is not the case with the lime-stones of the coal countries. These are found as regular as the coals which they accompany, and the coal strata are more regular in continuation upon the bearing, as far as the class of strata belonging to the coal reaches, than any other that I have investigated; and I look upon it, that this observation may be of use in practice.

The mason and the farmer may wish to find a known lime-stone at some distance from the place where it is seen. Let them keep the line of stretch or bearing of the strata, and in the coal country they will be sure to discover it at nearly the same parallel distance from a seam of coal or other given stratum, as at the place where it was last seen. But the discovery of mountain lime-stones, in the same way, is less to be depended upon. Though you may have a good and plentiful quarry in one place, yet, perhaps half a mile, or half a quarter of a mile further forward, you cannot discover it, because it is not to be discovered.

I have observed above, that the lime-stones of the coal countries are always regularly stratified; some of which strata are very thick, others very thin. The lime-stones of the coal-fields are often distinguishable, by containing a great variety of shells, coral, and other marine bodies, which are found blended in the heart of the stone.

6. Marbles of various colours and degrees of beauty and goodness. Some of these are found regularly stratified in layers of middling thickness, but they are oftener met with in thick irregular beds, which are generally broken transversely into blocks and pillars of various sizes, from one thick stratum. Among these, the fine white statuary marble of Assint in Sutherland, is the purest and best I ever saw. I am persuaded there is none bet-

ter in Europe, and there is enough of it to serve all Britain, perfectly solid and pure, free of blemishes or stains; and blocks or slabs of any size may be cut out. But there is bad access to it, nor would it be easily quarried, there being a little cover above it, of a soft, loose, whitish lime-stone.

This marble accompanies a prodigious rock of grey lime-stone of a granulated texture, which appears in regular strata at Assint; but it is one which varies in thickness as you advance along the bearing of the strata. The good white marble of Assint is only to be seen in the bed of the river, about a mile or two south of the church.

It is to be regretted, that we should send to foreign countries for stones, for the purpose of ornamental architecture, when, perhaps, no country can produce so great a variety of the most excellent stones as are to be found in Great Britain; and therefore, in case posterity should grow wiser, I will point out a few of the places where I have seen singularly excellent stones.

A few miles from Blairgowrie in Perthshire, not far from the high road side, towards the north, there is an excellent, granulated, broad-bedded lime-stone, of a sugar loaf texture, and as white as the finest statuary marble. I look upon this to be a good species of the true Parian marble of the ancients; and as it may be easily raised in blocks and slabs perfectly free of blemishes, is of a pure

white, and free and easy to be worked in statuary and other ornamental architecture, I think it only requires to be well known to become of great value.

There is some of this species of stone in the Duke of Gordon's lands, in the forest of Glenavon, composed of fine glittering broad grains like spangles, as large as the scales of fishes, but the situation is remote, and difficult of access.

The fine white statuary marble of Assint in Sutherland, already mentioned, has a just title to an eminent rank among peculiar and excellent stones; and of this there is enough to serve all Britain.

Near the farm-houses upon the north side of the ferry of Ballachylish in Lochaber, there is a lime-stone or marble rock, of a beautiful ashen-grey colour, and of a fine regular uniform grain, capable of being raised in blocks or slabs of any size, and capable of receiving a fine polish. This singular rock is finely sprinkled throughout with grains and specks of fine bright mundick or pyrites, and likewise with grains and specks of beautiful lead ore of a fine texture, which to the eye appears to be rich in silver. This would make a bright and beautiful metallic marble.

In the farm of Blairmachyldach, about three miles south of Fortwilliam, in the bed of a river, there is a very singular marble, consisting of a black ground, and flowered with white. This

stone is of a fine close grain, but not very hard; the flowering in it is light, elegant, and beautiful, like fine needle-work, or rather resembling the frosty fret-work upon glass windows in a winter morning; and it is not only upon the outside, but quite through all parts of the body of the stone.

Jasper, of which there is an extensive rock, near Portsoy in Banff-shire; some parts of which contain a beautiful mixture of green and red, &c. which appear finely shaded and clouded through the body of the stone when polished. I saw chimney-pieces of this stone in the old ruinous house of the Boyne in that neighbourhood, in which a considerable portion of red is shaded with the green, and spread out in beautiful clouds through all parts of the stone. These jambs and lintels were exceeding beautiful, and retained the lustre of their polish undecayed. This would be a valuable jasper quarry, if properly opened; but as the body of the rock is hard and ill to work, I have seen no good specimens of it, excepting the above-mentioned old jambs *.

Agate. There is a large patch of fine agate upon the side of a hill near the church of Rothes in Moray, chiefly of a fine mixture of the red and

* This rock, denominated *jasper* by the Author, is the *serpentine* of mineralogists.—EDITOR.

white colours. This is a very beautiful rock, is very hard and heavy, of a fine smooth uniform texture, of considerable brightness, the red and white being remarkably cleared, and finely mixed through the stone, and so hard as to be susceptible of the highest lustre in polishing.

Porphyry, of which a great part of the hill of Ben Nevis in Lochaber is composed. The porphyry of Ben Nevis is a beautiful stone, in which the pale rose, and the yellowish white colours, are finely blended and shaded. About three-fourths of the way up this hill, upon the north-west side, there is found a porphyry of a greenish colour, with a tinge of a brownish red. This stone is smooth, compact, hard, and heavy, of a close uniform texture, but of no brightness when broken. It is spotted with angular specks of a white quartzy substance.

Granite. The finer and most elegant red granite, and the finest granite-like porphyries, are so near a-kin to one another in quality and appearance, that I will not attempt a distinguishable description of them *. Scotland is remarkable for a

* In granite, strictly speaking, there are three component parts, quartz, feldspar, and mica; which are generally so distinct as to be easily discriminated by the eye. In porphyry, the feldspar crystallized is inserted in some base, as, for instance, trap or pitch-stone, so that here two component parts only are obvious.—EDITOR.

great number and variety of granites. The elegant reddish granite of Ben Nevis, near Fortwilliam, is perhaps the best and most beautiful in the world; and there is enough of it to serve all the kingdoms of the world, though they were as fond of granite as the ancient Egyptians.

There are extensive rocks of red granite, upon the sea-shore, to the west of the ferry of Ballachylish in Appin, and likewise at Strontian, as well as many other parts of Argyleshire. I have seen beautiful red granite by the road side, north of Dingwall, and in several other parts of the north of Scotland, which had been blown to pieces with gunpowder, and turned off the fields. There are extensive rocks of reddish granite about Peterhead and Slains; and both of red and grey granite in the neighbourhood of Aberdeen. The hill of Cruffel in Galloway, and several lower hills and extensive rocks in that neighbourhood, are of red and grey granite.

Basalts, of which there is a very great variety of the grey kinds in many parts of Scotland, and some of them are capable of the brightest polish. There is a good black stone of this species, formed into large columns, upon the south side of Arthur's Seat, near Edinburgh, of a fine uniform texture, and a good black colour, and capable of receiving a very high polish. This stone would be peculiarly fit for ornaments about sepulchral mo-

numents. It will polish to a bright, beautiful, and unfading black.

Stone-marl, or soft lime-stone, commonly found within regular strata, and of all colours. I have seen of the stone-marls red, brown, purple, hasle, grey, bluish, ash-coloured, and white, and some of them variegated.

The greatest quantity of the stone-marl dissolves upon the land in a few weeks, or at farthest in the course of a season; but there are found in some stone-marl pits particular strata, so hard as not to dissolve upon the land at all without burning it into lime; and yet, immediately above and below these hard beds, the marl is soft enough to dissolve in a short time.

Chalk, some of which is regularly stratified; but a great deal of it appears in thick irregular masses. It is now a long time since I was in the chalk countries, so that I do not pretend to be able to give a perfect account of this remarkable calcareous fossil. I have seen fine white indurated chalk brought from Ireland for burning into lime, in which the flints are promiscuously blended, as in the common chalks of England, the masses of which appeared to me to be broken off from regular strata when quarried *.

* This is properly a lime-stone; for it is extremely hard. Its fine white colour has probably led the Author to consider

IV. The micaceous mountain rock, which is of a blackish and dark grey colour, hard and heavy, of a longitudinal texture, is exceedingly strong and difficult to break across the grain. This stone contains particles of quartz, schorl, and pyrites, frequently of iron, and commonly holds so much mica in the composition of the stone, as gives it a bright metallic appearance. There are extensive mountains of this stone in many parts of the Highlands, and in Galloway. It generally appears in pretty thick strata, which naturally break into flattish glebes of various sizes, but generally all very large.

V. Basalts, which abound in Scotland, of which a considerable quantity was carried from the Frith of Forth to London, for paving the streets. This stone is very strong, hard, and heavy, of a black, or blackish grey colour. Sometimes it is pretty fine in the inside, but more commonly of a coarse granulated texture. The principal parts in the composition of this stone are grains of different sizes of quartz and schorl, as appears by the black and white glittering particles in it; and it commonly contains some iron.

This stone always appears in thick irregular beds, and is found in many parts of Scotland, in

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it as chalk, which indeed differs from lime-stone only in its state of coherence.—EDITOR.

high and low lands, in the isles and coal countries. Some of the beds of basalts are of enormous thickness; and where no other strata are found above, it is seldom of equal or regular thickness: On the contrary, where it is found uppermost, it often swells into little hills of various sizes. Most of the small islands in the Frith of Forth are rocks of this stone; and several hills in the neighbourhoods of Inverkeithing and Edinburgh, are formed of thick beds of basalt, such as Arthur's Seat, &c. Of this singular rock there are several varieties.

The most distinguishing characteristic of the basalt is this: It assumes various figures, such as columns, glebes, balls, &c.

As to the *first* of these: The columnar basalts are frequently found formed into pillars of various sizes and lengths, having five, six, and seven sides; but columns of a quadrangular figure are not common. These columns are all smooth on the outside, and lie parallel and contiguous to one another, sometimes perpendicular, and often inclining in proportion to the position of the stratum, which is thus divided: If the stratum lie horizontal, the columns are perpendicular; if inclining, the pillars also incline in exact proportion to the declivity of the strata, they being always broken right across the stratum.

Some of these pillars, of various lengths, are only one entire piece from top to bottom; others are

divided by one or more joints or pieces laid upon one another, which form a column of several parts. The rock called the Giant's Causeway, in Ireland, as it is described, is a remarkable example of the jointed columnar basalts.

The basalt in some places is formed into magnificent columns of great length; and in other places exhibiting an assemblage of small and beautiful pillars, resembling a range of ballustrades, or organ pipes. Some very long columns appear on the south side of Arthur's Seat, near Edinburgh; and there are several magnificent columns of great length, in the island of Egg, and many other places *.

The columnar basalts, when broken, are frequently black, or of a blackish grey colour in the inside. Some of it is composed of small grains or particles, which give it a tolerably smooth and uniform texture; and much of it holds larger grains in the composition, of a rough, sharp, and unequal surface in the fracture. But all the grains are fine, hard, and bright; and as the stone is compact, it is generally capable of receiving a very fine polish.

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* The island of Staffa affords the finest example of columnar basalt in Britain. On the west side of the island of Mull, in the island of Cannay, the Schant Isles between Lewis and Skye, and others of the Hebrides, columnar basalt is not uncommon.—EDITOR.

2. The second species or variety of the basalts I will take notice of, is not formed into columns, but into glebes of various sizes and figures, some of which are nearly quadrangular, or of a flattish square, with obtuse edges, and some of it assumes a roundish form; and these masses are found of all sizes, from the bigness of an egg to the size of a house. Although these stones differ from the columnar species in figure, they nevertheless have an exact resemblance in almost every other respect. In short, the only distinguishable difference is the external figure, so that I think they can only be reckoned as varieties of the same species of rock.

It appears to me very evident, that this stone was broken and separated into this great variety of figure and size, by the cracking of the mass of matter, while the rocks were soft and humid, before induration was completed, the stony matter shrinking into less room, as the moisture was draining off by evaporation, and otherwise. The inequality of the sides of the columnar basalts, and of the size and figures of the glebous, is to me a clear proof of their being first formed by the cracking of the stratum while the water was exhausting.

It is a very common thing to see one stratum of the basaltine rock exhibiting in one place regular pillars or glebes, and near them very irregular ones, differing little from the common cutters which are found in all rocks; and at no great

distance, the same rock is found run together into one entire mass. This observation is verified in the stratum of basalt, which is formed into pillars on the south side of Arthur's Seat, near Edinburgh, as well as in other places; which makes it evident, that the formation of some part of such rocks can proceed from no other cause but the loss of humidity.

Some of these rocks only produce solid masses, while others produce different quantities of a softer friable matter, in which the hard masses are imbedded. Pretty good specimens of the second sort of basalts are to be seen by the road side, between Cramond bridge and the Queensferry, and in several other places in the Lothians and Fife.

3. Crustated basalts, which is not only formed into glebes and masses of various sizes, imbedded in a less or greater quantity of the softer friable matter mentioned above; but these masses are also crusted round with several coats of the same basaltine matter, though these crusts are in some degree more loose and friable than the solid masses of the basalts.

I have seen many quarries of this rock dug for the high roads, where the softer friable matter exceeded the hard masses in quantity, and in which encrusted stones of various sizes and shapes appeared. Some of the largest masses in such quarries have only a few coats of penetrable friable

matter, surrounding a nucleus which varies in size, but which is uniformly hard throughout.

The decomposition by the weathering of the softer matter, found surrounding and enveloping the harder masses of stone in this and the second species of basaltine rocks, has produced a phenomenon frequently met with in Great Britain, especially in Scotland, which greatly puzzles many. It is very common, in low grounds, and upon some moderate eminences, to see a prodigious multitude of stones of all shapes and sizes, very hard, and pretty smooth on the outside. These stones are sometimes so numerous and large, that it is often found impracticable to clear a field of them. Where those stones are a species of the basalts, which they commonly are, and of the second class or species described above, in that case they always originate from the decomposition of the more soft or friable parts of those rocks, which moulder and fall away, and leave the harder stones detached and scattered about, and the decomposed matter dissolves by degrees, and becomes good soil.

The singular appearance and enormous size of many of these stones, make many people, and even men of letters, imagine that stones grow like vegetables; but it is very evident to our senses that stones cannot grow. They may, and many of them do, wear less and less, but they cannot grow larger, excepting in situations where there may be

an accretion of particles of matter carried and deposited by water, by which process concretions and petrefactions are formed. These stony productions are formed and increased in size by the continual accretion and addition of matter deposited by water upon the outside; but this differs widely from vegetation. Others imagine that these stones were rolled about, the asperities and sharp angles were by that means worn off, and that they were all at last deposited as we see them by the waters of the universal deluge. I have taken great pains to investigate this point, having frequently examined circumstances, and never failed to discover the stratum of rock from which these detached stones originated.

4. Crustated basalts, which is dry and friable throughout the whole mass. This species of the basalts is generally of a coarse granulated structure, and of all the various shades of the grey colours, from a rusty black to a light coloured grey. We see this species of crustated basalts developed when the masses are either broken or decomposing. There are masses of this stone of all imaginable sizes and shapes found in the rock, resembling in figure and size the second and third species of the basalts, and they appear alike smooth on the outside, with obtuse angles, in short, resembling the other basalts in every respect; but when exposed to the external air and weather for any con-

siderable time, the several incrustations decompose, and crumble down by degrees.

5. Composite basalts, resembling the three last species in figure, colour, and all external appearances, as it is found in the rock, and in loose detached masses, but distinguishable from them only in the inner structure and grain of the stone.

This species of the basalts, which I call the *composite*, is not unlike some of the granites, as it is composed of much larger grains than the other species already described. Some of the larger grains in the composite basalts are a fourth, and many of them more than an eighth of an inch over, and they appear with smooth flat surfaces, and of a tabulated texture, exactly resembling the large quartzy grains so commonly found in the composition of most of the granites *.

6. The last species of this stone that I will take notice of, is that which is indurated through the whole stratum, solid and uniform in all parts, and only exhibits such cracks and fissures or cutters as we discover in all hard beds of stone. We meet with many beds of this species frequently in the coal-fields, and are often obliged to sink through them in our coal-pits. The Salisbury Craigs near Edinburgh might be singled out as a

* This is the greenstone mentioned in a former note.—EDITOR.

good example of this species of stone, were it not that part of the same stratum is formed into columns upon the south side of Arthur's Seat; though I believe this is no good exception, as it evidently appears that the beds of basalts which are formed into columns, glebes, &c. only assume those figures where they are exposed to the influence of the external air, or have but little cover of rock above them. When any of those beds strike deep under the cover of other strata, they are not found in columns, &c. Nothing but an uniform mass then appears, although the same bed is regularly formed near the surface; which proves, that the columnar and other basalts are formed by cracking and shrinking.

In the Bathgate hills, south of Linlithgow, and in many other parts of Scotland, there are several strata of basalts, and also several strata of coal, of lime-stone, freestone, and other concomitants of coal, blended promiscuously, *stratum super stratum;* and the basalt is frequently found immediately above, and immediately below regular strata of coal; of course, basalts is not the lava of volcanoes. We can prove to ocular demonstration, from the component parts, and from the situation, stretch, and bearing of the strata of basalts, that they are real beds of stone, coeval with all the other strata which accompany them; so that if basalt be a volcanic production, so must all other strata be of necessity: but how volcanoes should

produce coal, and how that coal should be regularly spread immediately above and below strata of lava, is a little problematical; or rather, it is strangely absurd to imagine, that burning lava can come in contact with coal without destroying it.

VI. The breccia, or plum-pudding rock. This rock exhibits a very singular appearance in the superficies of the globe. It is composed of bowlders and water-rounded stones of all qualities and of all sizes, from small gravel up to large bowlders, or rounded stones of several hundred pounds weight; the interstices being filled up with gravel and sand; and it frequently contains lime and iron.

When the breccia or pudding-rock contains many large bullets of various colours and figures, it exhibits a formidable and grotesque appearance, discovering no marks of stratification, but appearing in one prodigious mass, and frequently swelling to the height of a considerable mountain. This curious rock is often so strongly cemented together, that it frequently overhangs in frightful precipices, which are less apt to break off than many other rocks in such situations; and the reason of this strong cohesion is, that this rock is frequently found in one solid mass of great extent and thickness.

It appears evidently at first sight, that all the

parts of the breccia, whether coarse or fine, have been rounded by agitation and attrition in water, as the rocks differ nothing in appearance from the coarser and finer gravel found upon the beach of the sea, excepting only that the parts are strongly cemented together.

I have seen some of the breccia composed of finely rounded stones of various beautiful colours, about the size of plums and nuts, and all very hard and fine. If this stone were sawed and polished, it would appear as beautiful and elegant as any stone in Europe; much resembling Mosaic work in small patterns, and receiving a brilliant lustre.

The breccia generally appears regularly stratified, or not, in proportion to the size of the component parts of the stone. Such rocks of it as are composed of round gravel and small bullets, are generally as regularly stratified as common sandstone. Such, again, as hold bullets, like the first, and something larger, are commonly disposed into thick coarse beds; and such rocks of it as are composed of the larger bullets seldom show any marks of stratification at all. There are extensive tracts of this rock in many parts of the Highlands and north of Scotland.

VII. The regularly stratified quartzy mountain rock, of a white colour, a little tinged with a blue cast, and often of a bluish grey colour,

In some parts of Britain this stone is rare. I have seen some little of it in the north, and it is very common in the Highlands of Scotland, where I have frequently seen it as regularly stratified as any of the sand-stones, with other regular strata of different qualities immediately above and below it; and sometimes composing large and high mountains entirely of its own strata. This stone is exceedingly hard, dry, and brittle, full of cracks and sharp angles; the different strata sometimes moderately solid, but often naturally broken into small irregular masses. There are high mountains of this stone in the shires of Ross and Inverness, which in a clear day appear at a distance as white as snow, without any sort of vegetation on them, except a little dry heath round the base of the hill.

VIII. The coal metals are a very numerous class of strata; but as I have already examined them particularly, I will only take a cursory view of the sand-stones, of which there is a great variety in colour and texture; and they are disposed into thick, middling, and thin strata. The regular broad-bedded freestone, of a laminated texture, commonly rises in middling and thin strata; and appears at the edges of a section, when broken or cut, to be formed of different thin laminæ or layers of sand, equally laid on the whole breadth of the stone, and well cemented together.

I have seen a great deal of both red and white freestone rise in layers of five or six inches, and upwards; and when a slab was polished, regular streaks, of a fifth or sixth part of an inch, appeared the whole length of the stone, as if laid on by so many gentle waves of water, spreading over each layer. The flaggy grey strata, the strata of slate in general, and many of the black and grey strata of the coal metals, may also be ranked with this freestone, for perfect and regular stratification; and likewise may other thin strata of the coal metals.

Many of the grey regularly stratified mountain lime-stones are also streaked or striped; and the streaks in these appear more conspicuous, when broken, than the streaked freestones; the colours of the parallel streaks or stripes being brighter. I observed before, that some of the hard regularly stratified mountain rocks are streaked; and in all these three different stones, it is to be remarked, that the streaks are all regularly and exactly parallel to the bed of the stone; which sufficiently proves, that the same agent was employed in the formation of these, and of all the completely stratified metals, and that this agent acted with much regularity.

IX. The grey flaggy strata of Caithness afford another remarkable instance of regularity. The rocks of all the low country of Caithness, a square

of ten or fifteen miles, are bluish grey argillaceous strata, with generally a small quantity of lime in the composition of the stone, which is indurated to a greater degreee than is common to such thin strata. This stone is strong and tough; and all over this country it is disposed in thin, broad-bedded, regular strata. In several parts of the country, these flags are so thin and regular, and are raised so light and broad, that three or four of them cover the side of a small house.

CHAP. II.

OF THE STRATIFICATION OF THE SURFACE OF THE GLOBE, OF THE CONTINUITY OF THE REGULAR STRATA, AND OF THE INTERRUPTIONS TO WHICH THEY ARE SUBJECT.

All the phenomena of the strata, and the partial history I have given of them, make it evident to me, that those rocks which are laminated, and spread out one above another, were formed by the waves of water put in motion by the tides and other natural causes; and that other rocks, such as most of the granites and pudding-stones, some of

the basalts and lime-stones, &c. have striking appearances of the stony matter subsiding in deep water;—for subsidence cannot properly take place in water greatly agitated, or flowing with a strong current.

It now begins to be acknowledged by almost all those naturalists who inquire into the nature of the mineral kingdom, that they see the marks of water every where upon the superficies of this globe. M. Buffon asserts, that every thing we see, both upon and within the surface of the earth, carries self-evident marks of the whole being formed by water; and he is evidently right, in general, in asserting, that water was the agent in this great work, but he is as certainly wrong in his account of the manner of performing it. But from all the phenomena, it appears that the materials which compose our rocks and strata, must have been mixed with water in a fluid or chaotic state, when the superficies of the globe was formed, and its materials were arranged. At present I will take it for granted: I shall have occasion to resume the subject hereafter, and to make various inquiries relating to this chaotic state of our globe.

It is natural to suppose, that the diurnal motion of the earth from west to east upon its own axis, and the motion of the tides from east to west, were not suspended while this planet was in a chaotic state, before the present dry land appeared. Upon this supposition, it seems to me highly pro-

bable, that those strata which we see disposed in regular order, were formed by the tide spreading out the grains and particles of stony matter upon a large plane, and leaving them there. The phenomena of the strata themselves, and a slimy sediment found betwixt the beds of many quarries, make this hypothesis abundantly evident. Most of the granites and breccia, some of the basalts, lime-stones, and others not regularly stratified, I suppose were formed by the stony matter subsiding when the water was in some degree of rest at the height of the tide, or from other causes of stagnation. Great quantities of matter, lodged by a particular high tide in different places, might make many large temporary obstructions by water containing great quantities of stony matter, which would subside into a thick irregular stratum during the recess of the tide; which obstructions future high tides would break down and sweep away.

I am convinced, by the phenomena of the strata, that every stratum which we see regular was formed upon the surface of the globe; that is, that the very part of the globe where a particular part of the stratum was made, began to be dry land before the tide brought with it the matter which produced that stratum; and so on, *stratum super stratum*, tide after tide, until all the strata were completed. And perhaps higher and lower, stronger and weaker tides, might have been the

cause of thicker and thinner strata amongst those we call regular. We find the thick and thin strata very unaccountably mingled, unless we will allow such a natural cause as the difference of tides.

I am also convinced, that when every individual stratum was made by the tide, that stratum was spread out by the water upon nearly an even level plane superficies, extending the whole length and breadth of that stratum; and that the inequalities of declivity, the fractures and various irregularities we meet with, happened after the strata were spread one above another upon a level surface.

To compare great things with small, the strata of sand and mud lodged by great rivers in plains, by inundations from the mountains, are disposed in layers very much resembling our strata of stone, &c. I have read an account of a deep well or pit dug in Holland, in which they found thicker and thinner strata of clay, mud, and sand alternately, to the depth, if I remember rightly, of about thirty or forty feet. There is no room to entertain a doubt, that these strata of loose matter were spread out there at different periods of time by the inundations of the Rhine, &c.; and those several strata dug through in Holland, being found in a loose state, without any appearance of cement or induration, is a proof of an observation I made in another place, viz. that such adventitious stra-

ta as are formed by accident upon the shores of the ocean, the banks of rivers, &c. at any time since the first formation of the superficies of our earth, want the cementing quality which binds and connects our rocks with various degrees of cohesion. These adventitious strata assist our ideas in forming a proper notion how the great work of the stratification of the superficies of our globe proceeded.

I hope it will be acknowledged, that this account of the formation of the strata and rocks upon the superficies of our globe, appears natural: At the same time, I am sensible it may be supposed at first sight, that it points at regularity, which is no where found in continuation. I hope, however, to convince every unprejudiced inquirer, that all the declinations and interruptions to regularity, observed in the strata, are, upon this hypothesis, natural and necessary. For, let us suppose that the interior parts of the earth, below the visible strata, were formed by subsidence, and that from the agitation of the tides, this interior rock, as we may call it, would be full of inequalities upon its surface, before the exterior rocks and strata were formed; the great agitations of the waters, and the great run of those high tides from east to west, would undoubtedly carry and lodge the stony matter in great inequalities. Admitting the chaotic state of the terraqueous globe, it is impossible to conceive that it could be other-

wise; and the phenomena of the granite and pudding-rocks greatly countenance and illustrate the position. Several mountains in Lochaber and in Appin, the mountains of Cairngorum, amongst many others in the Highlands of Scotland, and Cruffel in Galloway, show us how the granite rocks are most commonly formed. The pudding rocks upon both sides of Loch Ness, in Ross-shire, Sutherland, and many other places, exhibit similar phenomena.

In the cursory view I took of the prevailing rocks in Scotland, it appeared that there is, comparatively speaking, but a very small part of the granite rocks found in regular strata. Sometimes this rock lies moderately flat and level, and often disposed into low inequalities; but its most common appearance is in hills and mountains, some of which are of great magnitude and height; such, for instance, are the mountains of Lochaber, Appin, and Cairngorum, in the Highlands, and of Cruffel in Galloway. The most of these mountains, and many others of the same quality, are composed of one entire stone or mass, from top to bottom, without the least appearance of strata, or any divisions into different layers or beds; and often with very few of the common fissures or cracks, which are so frequently found in other rocks. In the course of a rivulet, on the east side of Ben Nevis, in the Highlands, I examined the granite rock, which was washed clean for the space of

four miles, and I could perceive no appearance of any division or bed, or hardly a crack or cutter, a quarter of an inch wide. The whole rock was uniform and equal, like the surface of a single block of stone. Now it is impossible to meet with any thing in nature, that can give us a clearer idea of the stony matter subsiding in water with unequal superficies, than these mountains of granite, and the lesser hills of breccia or pudding-rock, exhibit.

Various phenomena make it evident, that the tides rose to a prodigious height during the formation of the rocks and strata which compose the surface of the globe. The fluid chaotic state of the terraqueous globe, was one reason of such high tides at that period. The attraction of the sun and moon would have a greater effect when the whole surface was in a fluid state, than when part only was fluid and part solid. From the tides rising so high in that state of the earth, originated many mountains of granite; some of which, though high, must have subsided altogether in one tide; this is evident from their containing the same matter without any variation in quality or colour; and from their being one uniform mass, without strata, division, or bed, from top to bottom, that can give us the least indication of the matter being laid on, or subsiding at different times. But this is only to be understood as

meaning such parts of the mountains as are in our sight.

As it is evidently matter of fact, that the mountains of granite are of the construction which I have described, it must be acknowledged that the tides were high when those mountains were formed. In this case the effect proves the cause, and the cause naturally accounts for the effect. Now, from these known facts, which we can investigate, we may form probable conjectures in cases perfectly similar. When we see inequalities upon the superficies of the granite, and other rocks formed by subsidence, so considerable as to rise to the height of great mountains, it is rational to conclude, that similar inequalities would be occasioned by the subsidence out of our sight. During the first periods of the subsiding of stony matter in the waters, I think it a reasonable supposition, that the interior parts of the globe would consolidate before the surface. Besides the pressure of the superincumbent chaotic matter, the attraction of the sun and moon would be more powerful near the surface than further down, which would help to keep the more superficial parts of the chaotic or earthly matter more loose and mixed with water; and of course, the sediment near the surface of the globe would be last in forming, and would be very humid and cavernous, as well as unequal.

LET us now proceed to account for the inequalities and breaks of the strata. When the surface of the consolidated parts of the globe began to rise so high, or nearly so high, as the surface of the globe, that the tides would begin to run and form strata, the first as well as the last of those strata would be spread out even and smooth upon a large surface. Now the first of these strata would be spread out upon a very unequal and insufficient ground, which was not only of a mountainous figure, but also containing a great quantity of water in the composition of the sediment; and some of the caverns and hollows would be much more humid and slimy than others; and therefore, when the weight of the superincumbent strata was laid by succeeding tides above this unequal, terraqueous basis, and when the superior waters began to lessen in bulk and weight by the separation of the earthy and stony matter, and to retreat by degrees to the present bed of the ocean, and much dry land began to appear between tides, before the induration of the strata had taken place, it became necessary that the water contained in the caverns and hollows, and in all the humid sediment below the strata, should find its way out. The weight of the superior strata, as yet humid, soft, and flexible, would press hard upon the unequal ground below; and this pressure would in time become so great, that the water below must force its way out, by breaking the superior strata

in many places; and this forcing up of the interior water, drained out of the humid sediment, is the origin of all the caverns, gashes, veins, and fissures we so often meet with, and behold with astonishment. A great quantity of water forcing its way out would make a large passage; and the violent manner by which this passage was made, would greatly disturb and distort the strata near the rupture. When the water had forced its way out with a violent eruption, the strata being still tender and humid, the aperture or cavern would, in whole or in part, be filled up by the falling in of the sides or roof, which would disturb regularity, and produce confusion and disorder a good way round. While the superior strata were borne up by the waters beneath, and continued whole and unbroken, they were all horizontal and level, or nearly so; but when the interior waters forced their way out, by bursting the strata, there would be formed considerably unequal vacuities underneath the strata; and of course, the strata being not yet indurated, there would soon be great alterations upon the surface of the globe.

The yet humid and tender strata would bend and break in many places, and sink down into the vacuities beneath, which has caused the various declivities, ruptures, and other interruptions of the regularity of the strata, which we every where behold. Where the interior vacuity was very deep, the parts of the strata immediately above such va-

cuity would be depressed so low, that the other parts, which would rest upon the side of an interior mountain, would be turned up nearly on edge. The strata would dip and lean into these interior lakes, gulphs, and vacuities, with all the varieties and degrees of slope, of elevation and depression, which exist.

At Springkell in Annandale, a deep lime-stone quarry exhibits the under or concave section of an arch. From a profile view of this section, it appears that the uppermost stratum of this rock is very short, as that small segment of the arch soon cropped out to the north and to the south. The second stratum downwards is considerably larger than the first. The third and fourth, and so on, continued to lengthen all the way down to the bottom of the quarry, as both ends or sides of each stratum below came round and cropped out at the surface, as high as the upper stratum cropped out; so that all the lower strata took an ample sweep, and formed the concave semicircle of a magnificent arch.

I know not how to account for this curious phenomenon, without admitting a cavity underneath the strata, into which the middle of them was depressed, and the sides elevated while they were humid and pliant. A cavity of a certain extent would occasion the strata above to fall into just such a degree of slope as the size and figure of the hollow below would admit of. Where the ca-

vity was deep, and the sides of the subterranean mountains very steep, the strata above would fall nearly on edge; and when shallow, they would only be depressed a little, which would give them an easy slope or declivity, and so on to all the intermediate degrees.

When a small vacuity happened to be greater under one side than the other of a class of strata, the weight of the strata over such vacuity pressing down on one side, and the resistance of the other side, which was supported below, would at last cause them to break across, and the strata upon one side of the breach would sink down, and the edges of the several strata would slide past each other at the fracture, so that the edges of those which sunk down would fall below the edges of those which stood firm as many feet, or as many fathoms, as the vacuity below was deep or shallow; which was the cause of all the slips and hitches which we so frequently meet with in coal-works and quarries, and which we see in other places where the strata appear.

I apprehend we may find another source of water to disturb the regularity of the strata, besides what I have attempted to explain. The superior strata and rocks formed by the water and in the water, as the matter was laid on by the streams, or lodged in sediment at the height of the tides, would all at first be in a soft and humid state, containing a considerable quantity of water, which would all by degrees ooze and drain out by the

pressure of the superior upon the inferior strata. The water contained at first in the superior strata, when passing downwards by percolation, might for a while lodge betwixt some strata, or in any vacuities it might find; but when the superior pressure became greater, by the addition and settling of the strata, this water would also force its way out; and this, very probably, is the physical cause of many of the lesser disturbances.

It appears to me probable, that the water drained out of the strata, and afterwards forced out from between them, might occasion that sort of disturbance in the coal metals and others, which I have called a waving shake; and perhaps some of the lesser twisted shakes might have the same origin. I can easily conceive, that in many places, this water would be forced out with prodigious violence by the great weight of the strata above. In the formation of the strata by water in motion, it is reasonable to suppose, that some places would contain more water in the mud or newly formed strata than others; and of course, such places would be more quaggy and weak than firmer places, which contained less water: A pressure on such a place would easily force a passage; and if such weak place were of small extent, the water might force its way upwards in almost a vertical direction, and so form a twisted shake or a single pipe vein. I make no doubt, that one or other of these causes has produced all the phe-

nomena we observe within the surface of the earth, wherever we meet with any thing that disturbs or interrupts the uniform regularity of the strata.

It is a common saying with many, when they meet with phenomena in the mineral kingdom which they cannot comprehend, to call them "the "sport of Nature;" which is at best but a vague expression, frequently made use of to conceal ignorance. I think it a much wiser saying, made use of by others, viz. "That Nature does nothing "in vain." I cannot help thinking that the last saying is remarkably applicable to the subject under contemplation. Granting the strata to be formed by water, and I do not see how it can possibly be denied by any who take the trouble to examine circumstances, we must then suppose a great quantity of water to be contained in the composition of each stratum at first, and that this water would filter and strain out by degrees. It is as reasonable to suppose, or, in other words, it is necessary to allow this water a passage out somewhere. Go to a sandy or slimy shore, towards the latter end of the ebb of a high stream tide, when the sea retreats, and you will see how amazingly fast the water is oozing out of the stratum of sand which the waves formed, and the greater the slope is near the land, the quicker it drains out.

Allow, then, that the newly formed strata and unstratified rocks did contain much water at firs;

this water must find or force a passage out; and I have no reason to doubt, that the breaking out of the waters from beneath, and from between the strata, in greater or lesser quantities, from all depths, and in all directions and degrees of force, was the cause of all the great fissures, breaks, caverns, abruptions, twists, shakes, and other confusion and irregularities we meet with in the strata. I have seen examples which assisted to confirm my persuasion, that the greater the incumbent weight above where water broke out from a great depth, the greater and wider confusion it made, as appears in the strata in some places upon the shores of the ocean, under the sides of large granite mountains.

I have excepted the gashes, or the open fissures, which are wide above, and narrow below, from the interruptions of the regularity of the strata and rocks, which were occasioned by the eruption of the inferior waters. At the same time, I am perfectly clear, that the water contained in the sediment at first was the mediate cause of these gashes. The drying of the surface of the strata, by evaporation and percolation, was the immediate cause of them. When the great quantity of water contained in the mass at first, drained, evaporated, or issued out, the superior strata must shrink every way in bulk; and besides their diminishing in bulk from the loss of so much water, the strata, as I observed before, would fall, lean, and slide

every way, upon the water making its way from beneath them; and these effects jointly were the cause of the gashes, or wide chaps of the rocks and strata: Or, in other words, when the superior strata began to consolidate, and the water was drained out, they would crack; and the inclination of the strata different ways, would increase the crack to a wide gash. This part of the subject may be easily illustrated, even by small examples. We see the earth chap in a dry summer. A brick-maker's clay spread out, and left too long in the sun, without working, will soon crack all over. In the same way, I have observed in divers places, that the superior strata were chapped more than others below them. I mean, that a small part of rock or strata, spread over a limited extent of country of a particular quality, above which there is no appearance of there ever having been any other strata, and not much cover of any kind, exhibits the greatest number of chaps.

Whin-dykes were chasms at first, which were afterwards filled up by a high tide overflowing and pouring foreign matter into the gash; and the gash which continues open, or only contains sand or clay, or other loose matter, I suppose became gashes later, by the cracking of the surface of the rocks, after the high tides had so far retreated into their ordinary bed, that they would no more return to cover the earth.

We should not look upon all this irregularity,

which I have been describing, as forming real blemishes in Nature, of no further use than to answer the first purpose of giving vent to the superfluous water from the superior strata. I consider them all, or most of them, of great utility to man. The fractures in the superior strata, and their depression and elevation into various degrees of slope, give us an opportunity of viewing their edges at the sections we so often meet with, and of examining their crops or upper edges, by which we are enabled to choose what is useful, and to discover and work coals, quarries, &c. The great subterraneous caverns and passages often give vent to noxious mineral vapours, and are frequently the channels of subterraneous rivers, many of which run into the ocean, and into great lakes. Many of the gashes and larger fissures in the strata are the repositories where the mineral ores are treasured up for our future use, and we know where to find it and draw it out, as the advanced state of society, of commerce, and the arts requires it.

The smaller cracks and fissures which are met with in the strata, commonly called *cutters* by our quarriers, and which divide our quarry stones into so many blocks or masses, are considered by many as the effects of earthquakes and other violent concussions; but it is very evident to me, that they originate from another cause. Every person of observation and experience knows very well, that the

nearer the surface, the cutters appear more numerous; and *vice versa*, the deeper down there is the greater distance between them. I have seen many good quarries in which the strata were divided at the surface by these cutters into angular masses too small for use, which produced good blocks a little way down; and at a greater depth, there is often several yards square between these natural cutters, so that the quarriers are obliged to cut out every block of stone they raise. If these were the effects of earthquakes, &c. they would be found as numerous below as above.

In fact, they are the effect of the slow and gradual yielding and falling of the layers of stone closer to one another, after the water was drained out, and induration was taking place; and therefore we find them more numerous near the surface than farther down, because the surface was not pressed at first by the weight of any superincumbent matter; of course, it would contain more humidity, and retain it longer. When this was by degrees drained away, there would be the more room for the crops or surface of the strata to slide, and fall closer together; and their yielding and pressing together above, later than below, must necessarily occasion more cracks or cutters in each stratum at the surface than farther down.

This subject is so intricate, that I pretend not to unfold the whole arcana of Nature, or entirely to remove every difficulty and objection. But there

is one of considerable magnitude, which occurs at present, which I will attempt to obviate. The difficulty I mean, refers to my account of the strata I call regular, which, from their streaked and laminated textures, and their position one above another, &c. have unquestionable marks of being formed by the tides, or, in other words, by the flow or current of water in motion. I said, that the first of these strata was formed upon what began to be dry land, or where there was but little cover of water, or chaotic matter, at the ebb of tide; and if there were but two or three regular strata in all, this matter would appear very plain and simple; but as we see in some high cliffs of the sea, in deep rocky glens, among our highest mountains, and in sinking deep coal-pits, &c. many great and lofty sections of the strata, where we behold numbers of them in regular order, one above another, it may be difficult for many to conceive whence the great quantity of matter was to come from, which was requisite for composing all the rest, after the first two or three were formed by the flowing of water. There are two or three circumstances which contribute their joint assistance to enable me to solve this difficulty.

I suggested before, and I think it was a natural supposition, that the surface, or what began to be the solid superficies of the globe before the strata were formed, was soft and slimy, unequal and full of hollows, and mixed with a great quantity of

water. Now, when a prodigious weight of strata in a humid and flexible state was spread out upon such a ground, the water below would be forced out, and the superficies of the globe would shrink down considerably. All the strata, and especially the mountains of sediment, would grow thinner and be squeezed into less room as the water was drained out, and the prodigious weight of strata above pressed them together. This consideration helps in part to remove the difficulty started. The globe shrinking by degrees into less diameter, as the weight of more strata was added above, and the humidity drained out, the same height of tide would still spread out more strata. But this is not enough: it yet remains to be inquired, whence all the matter came which composed the subsequent strata? I answer, that part, and only the smallest part, would be carried out by the interior waters in their violent eruption when they burst their confines. When these waters forced their way out with such prodigious violence as the incumbent weight of a great depth of strata made necessary, when the superior waters had retreated, no doubt a considerable quantity of stony matter would be forced out with the water, which would contribute in part to form future strata: But the far greater part of the matter which composes the regular strata came from the bed of the ocean, which purged itself, by the motion of the tides, of all the sand and earthy matter which was before

mixed in the waters, and laid it upon the solid and higher part of the globe in regular strata; and the ocean does purge itself by the motion of the tides to this day. Though the larger rivers should carry down ever so much sand and slime into the sea, it throws it all out again upon the land.

It is easy to be perceived, from what I have advanced upon this great subject, that I am firmly persuaded the whole materials which compose the solid part of the surface of our globe were once entirely mixed with the waters in a chaotic state; and it appears from all the records of antiquity handed down to us, that this was a received opinion in the earliest ages all over the world. This was the chaos of the ancient poets and philosophers. In the raw and humid state of the surface of the globe at that time, it is to be supposed that strong and powerful winds would frequently infest the lower regions of the atmosphere; and these might have a powerful effect upon the stratification of the superficies of the earth, and in producing several of the present phenomena we behold upon the face of the globe. If we will suppose that many of these storms of wind were local, and only extended over a small part of the globe at one time, it is rational to suppose that these local storms of wind would have a mighty effect in driving or carrying the stony matter along with the

tides, and lodging it in strata in different places. Perhaps this is the reason that we every where find strata of the same quality in patches, which only stretch over a limited extent of ground, and then others of a different quality take place. But I will not enter into minute disquisitions of all circumstances. I only mean to give the great outlines of this extraordinary work of Nature. In all my researches, I have not been able to trace any particular class of strata for any considerable length of ground, comparatively speaking; for two or three hundred yards, and two or three hundred miles, are both of them inconsiderable, in comparison of a zone of the earth. I once took it for granted, as I believe many others do, that every stratum was a zone, or at least reached, I knew not how far; but afterwards having examined circumstances more accurately, I found I was wrong; and now frequent observation and experience have convinced me that there is no such thing as a very long stretch of the same class of strata.

As I hold that the surface of this globe was formed by the waters put in motion by the tides, it is necessary, upon this hypothesis, that the bearing of the strata should be due north and south between the tropics, and that they should deviate a little from this line without the tropics; on the north side, they should lean or bend a little towards the north-east, and upon the south side towards the south-east; that this deviation or bending

back of the line of direction, or bearing of the strata, should still continue and increase, as it advances from the equator towards the poles, so as to form an easy sweeping curved line across the semi-diameter of the earth, from south to north, &c. The attraction of the sun and moon upon the surface of the globe, is greater between the tropics than without them; of consequence, the tides must rise to a greater height at the equator than in the high latitudes without the tropics; and as the attraction is greatest between the tropics, and the tides would rise highest there, so would they run foremost at the equator (to compare again great things with small), as we see the stream of a swift running river in a flood. The current in the middle of the river is always highest, and bears foremost. But the greater degree of attraction between the tropics arising from the figure of the globe, and the situation of the torrid zone, makes it necessary for the tides to rise higher there, and to run with a forward head or current; and this would especially happen in the high tides in the chaotic state of the earth; and if the strata, in fact, appear in this supposed line of direction, it is a strong collateral proof that my hypothesis of the formation of the strata by the tides is true.

I have been told, that the bearing of the strata at the equator is true north and south; of the truth of which report I have not the least doubt, as it

appears necessary that it should be so. In these northern latitudes of ours, the line of direction or bearing of the strata, where they lie fair and regular, without being warped or thrown out of their due course by the influence of any particular cause, answers as nearly to my idea of the line of the tide, when the whole surface of the globe was in a fluid state, as can be imagined; and the strata in all this island, in high and low lands, in mountains and plains, bear to the same point in general. So far we can trace an exact correspondence between the cause and the effect; and I cannot help thinking that they mutually prove and illustrate one another.

It has been erroneously asserted by many, that the strata which compose the superficies of our globe, are disposed according to the true order of gravitation, the heaviest below, and the lightest above; but I have disproved this hypothesis in my observations on coal, where I have proved to a demonstration, that the lightest and the heaviest, with all the degrees and mediums, are blended promiscuously in the coal-field, without the least regard to gravitation. There we find free-stone, till, iron-stone, coal, till, free-stone, lime-stone, coal, iron-stone, &c. &c. alternately one above another, without the least regard to the laws of gravitation.

CHAP. III.

SYSTEM OF BUFFON EXAMINED AND COMPARED WITH THE REAL STRUCTURE OF THE SURFACE OF THE GLOBE.

I SHALL now proceed to examine part of the modern system of Mons. Buffon, &c. to see how it corresponds with the real structure of the surface of our globe.

In the discussion of this subject, I will not take the trouble to turn over the modern system or theories of the earth, in order to examine all their positions. Such an undertaking is too tedious for me, and is quite foreign to my plan, which is to communicate my own observations on the mineral kingdom; and therefore I will content myself with examining some of their general doctrines, and comparing them with the structure of the surface of our globe as explained above, which is known to every intelligent naturalist to be a true account of the matter.

" The earth (say the modern philosophers) grows old, like a mother no longer able to bear; but new earth (say they) emerges out of the o-

cean, fresh and vigorous, fit to bear and nourish plants and animals for some time, and then it sinks again."

Wild as this hypothesis really is, it must be acknowledged, that when it is attended by all the arguments which they have adduced in its support, it appears at first sight to have some shadow of truth on its side; but these shadows are illusive, and conceal the real truth from our view. The mother of a season grows old, it is true. and can bear no more; but the mother is renewed in the daughter, who bears in her turn, and so the race is continued. The earth receives annual supplies of soil equal to the waste, from the decomposition of the surface of the strata, from the fall of the leaf, and the decay of all vegetables; the seasons renew her youth, and prepare her to bear again with new vigour.

We know very well that Greece, Italy, and many other countries, which were once like the garden of God in fertility and beauty, are now comparatively barren and desert; but it must be remembered that those fields were green and fertile in the flourishing state of society in those countries; whereas now tyranny, horrid tyranny, reigns there.

Let us view this subject nearer home. How many extensive tracts of land in this island lay waste and desert in the time of the Saxon Heptarchy, during the contests between the houses of

York and Lancaster, and the longer contests and mutual invasions of the English and Scots before the Union, which are now green and pleasant fields, producing rich harvests, and adorned with gay and beautiful villas, commodious farm-houses, and populous towns. It is divine industry, attended and assisted by divine philosophy, when enjoying the blessings of peace and commerce, that enriches and adorns the face of the earth, that by the wise and liberal application of manure, and of alternate labour and rest, give her all the vernal bloom of the gay and youthful virgin, and the more ripe and perfect charms of the nursing mother; witness the wonderful revolution in the state of agriculture in this island since the Union.

When Greece, Italy, &c. flourished in verdure and fertility, industry and the arts, philosophy and commerce, went hand in hand, which encouraged population, and they were encouraged by internal peace and liberty. In a flourishing state of society under a mild and peaceable government, and wholesome police, industry and the arts reign triumphant. But, on the contrary, when countries are desolated, and continue under the baneful influence of tyranny and bad police, the best fields are soon robbed of their fertility, the rich vales become putrid marshes, the green meadows are overflown and sanded by inundations from the mountains, which before were kept within proper bounds. The higher grounds, and naturally poorer

soils, return to their ancient state for want of proper culture, and all the face of nature assumes a melancholy aspect of desolation. But let the scene be shifted again. Bring Industry, with all her friends about her, upon the stage, and the ensuing acts will be more glorious and satisfactory: Happy revolutions shall succeed one another, and the whole conclude in fertility, plenty, beauty, and joy. It is a known fact in agriculture, that the soil, so far from diminishing and failing to bear, on the contrary, increases under the hands of Industry, both in bulk and fertility, when managed with liberality and skill. But bad management is no rule by which to judge of the fertility of the Earth. She increases in richness under good management, and still produces plentiful crops, and will continue to produce so long as she is managed with industry and prudence.

Let us thoroughly consider the force of these observations. They will bear examination by every test; and if that attention be paid to them which their importance deserves, they will amount to a clear proof, that there is no occasion for the change of the earth contended for. But that we may do all justice to Count Buffon, and the other favourites of the new philosophy, let us, in the next place, examine the matter of fact; and it must be acknowledged, that some of the phenomena of nature seem at first sight to countenance and confirm their faith; but when we come to

examine these phenomena to the bottom, we find, that the conclusions drawn from them are not only demonstrably false, but that they are also big with the greatest absurdities, and infer consequences which are absolutely repugnant to the known laws of nature, and contrary to experience. It cannot be denied, that the ocean between the tropics has a strong current from east to west; and that this current has a considerable effect upon the eastern rocky shores in those latitudes, and in higher latitudes further to the north and south; whereever the tides set in strongly towards the land, they have very powerful effects in wearing down and gaining upon the rocky shores of the continents and islands.

Where the rocks are of a lax and open texture, their exposure to the action of the air, and the powerful beating of the waves, wash them down by degrees into small grains; but where they are more hard and firm, the violent dashing of the waves makes way into some softer veins and fissures, which by slow degrees undermines and brings down the hardest rocks, and then the fragments are rolled and agitated in the waters; and by trituration and friction one against another, these fragments are also worn down at last into grains or sands. It is also very evident, that many inland rocks, by being exposed to the action and changes of the atmosphere, by degrees decompose, and fall down into grains and sands; others

are undermined by the currents of rivers, rivulets, and lakes, which bring down fragments of them, the debris of which are worn down to sand, by the motion of the rivers, &c. as effectually as upon the shores of the ocean.

Thus far circumstances are in our sight, and they may be easily and truly investigated by every intelligent inquirer; and hitherto I agree with M. Buffon, but no farther. The conclusions he draws from these known and acknowledged premises are not true, and they infer many consequences which our experience of the phenomena of Nature assures us to be absurd and false. He says, "That the mountains and all the higher grounds melt down entirely by degrees, and that the sand and other spoils of the mountains and of the rocky shores are carried by the waters, and spread over all the bounds of the ocean, and that they subside in the waters, and form the several strata in all parts of the bed of the ocean, as we behold them upon the superficies of the earth: That the dry land which now appears was, in some ancient ages of the world, the bed of the ocean, and that what is now dry land will be under the ocean again in future ages; and *vice versa*, what is now ocean will be dry land: That not only the several strata of different thickness and qualities, and all the other phenomena we discover in the superficies of the earth, are formed under the waters by this supposed subsidence, but also that by

the currents and other motions of the waters, mountains, and valleys, and all the phenomena we behold upon the superficies of the globe, were formed under the waters of the ocean, and that the like are now forming for some future dry land." I will go a little farther in my concessions, and own, that all this appears plausible enough at first sight; but, however plausible the above conclusions may appear at first sight, when the circumstances concerned are well examined, we find that they are not true. The sand, &c. brought down from the mountains, and worn off the rocky shores, are not carried out and mixed with the waters through all parts of the ocean, in order to be formed into strata by subsidence; on the contrary, the sea purges itself of the waste of the rocky shores; and by that means the sandy shores are formed, which are the most effectual and most durable barriers against the ocean, to prevent its making any further encroachments upon the land. When once a sandy shore is effectually interposed between the ocean and the rocks, the rocks are for ever after preserved from any further injury or encroachment from the waves, as the sands always increase in a slow degree, unless there be a strong current in that place running parallel to the shore. Some of these currents, it is true, carry sand, &c. frequently a great way; but then the matter so carried by currents is thrown out upon some near or distant shore, where it contributes to

form sandy or slimy ground, and increases the dry land.

M. Buffon asserts, that streams of water always continue to carry down the dissolved strata, and to lodge it in the bottom of the sea, until the land is worn down as low as the bed of the ocean; and that when matters are in this state, the change is facilitated, the waters soon invade the dry land, and overflow it, and then new land emerges out of the ocean: And he further asserts, in support of this hypothesis, that all mountains are narrow ridges, or peaked at the top, which he says is a proof of their rapid advance towards this change.

I have already acknowledged that a considerable quantity of matter is carried down by the streams from the mountains; but this is altogether a trifling, unequal process, no way proportioned to the subject, and no such tremendous catastrophe can be concluded from it. It is not true that the summits of all mountains are peaked or narrow ridges. The extensive plains of New Grenada in South America are higher above the sea than the summit of Teneriffe; the country of Abyssinia in the old continent is nearly as high. Several other countries in many parts of the globe, especially between the tropics, are higher above the sea than the summits of any of our neighbouring mountains; and can we call any of these narrow ridges? Some of these elevated countries are some thousand miles of extent, and many of them

stretch several hundred miles every way. Ben Nevis in Lochaber is certainly the highest mountain in Britain. The summit of this mountain is broad, and the rocks upon the summit of it are so hard and tough, that I know not to what to compare them, excepting that wrought iron may come up to them in strength and cohesion, but it is far short of them in hardness. Now a hundred thousand years can be supposed to have but a very small and imperceptible effect upon this mountain; and many others are nearly of the same description as this.

With respect to the small quantity of matter that is carried down from the sides of the mountains by strong currents, it bears no proportion to the effects assigned. But the friends of this hypothesis may ask me, what becomes of it then? if I will not allow that strata were formed of it in the bed of the ocean, how can I dispose of it? I answer, that it is all well and wisely disposed of for the benefit and advantage of the present earth, and the inhabitants of it. Part of it is lodged in lakes, and in deep unseemly gulphs, in the course of the rivers, which are improved thereby into rich and pleasant valleys and plains, and the residue is carried along by the floods to the borders of the ocean, where it is very happily disposed of to form new land, which in fact enlarges the bounds of our habitations, and in time becomes the most useful, the richest and most convenient

parts of the earth for society and commerce, Great numbers of magnificent friths, extensive bays, long inlets and arms of the sea, have been filled up by the waste of the mountains, which are now improved into rich and plentiful countries; and upon which are built many flourishing towns and cities, which enrich those countries by their extensive commerce.

Rivers carry down more or less of earthy matter in proportion to their magnitude, and the extent of the surface from which their waters are collected. Great rivers, which have their sources in mountainous countries, carry down great quantities of matter to the valleys, and to the margin of the sea; and especially if those mountains abound in schistus, and other argillaceous strata, which are apt to decompose and dissolve into small grains: but then it must be considered, that this waste of the mountains diminishes in proportion as the softer soils fail, and the harder come to be chiefly exposed to the weather and the currents, and in proportion as the channels of the currents become more level and equal; so that in the course of time there shall very little come down with the waters.

When great and weighty rivers, which are apt to be greatly swelled by inundations from the mountains, pass through extensive desart woodland countries, they frequently tear up numberless trees by the roots, which are carried down by

the waters, root and branch; and these, when they arrive at the flats, are often intangled in one another, and lodged, heaps upon heaps, in all directions across the stream, and sometimes choke up the channel of the river, and turn it out of its former course. Extensive lakes and marshes are thus frequently formed; sometimes in large plains through which the rivers pass, but more frequently near the mouths of the rivers; and the lakes and marshes are by degrees filled up with new matter brought down by the rivers, which in time becomes rich and excellent soil. There is also a great quantity of sand, mud, and rubbish carried by strong rivers quite into the tide, but the tide throws it back again upon the land. A high tide, with a strong wind from the sea, and at the same time a great land flood, which frequently happens, often throws up great banks of sand and rubbish upon the bars in the channels of the rivers, and on both sides upon the shore, without the bars, which choke them up, and form large lakes and marshes; and these are likewise filled up in time by slime carried down the streams, and so the dry land is enlarged, and still continues to be enlarged, so long as a sufficient quantity of matter is brought down by such streams from the higher grounds; but I deny that any part of it is carried out to remote parts of the ocean, and there lodged in sediment. The strong currents of some weighty rivers, it must be owned, carry sand and slime a

good way out from the shore; and this is not always, and in all places, wholly thrown back by the tides upon the same shore; but strong winds, and especially strong currents running parallel to the shore, frequently carry some of it to a less and greater distance; but then it is assuredly thrown out by the tides upon some shore; for I constantly affirm that the sea purges itself by the motion of the tides of every thing thrown or carried into it, excepting only in these two cases: 1*st*, When masses of metal, or other ponderous bodies, are too heavy for the motion of the tides to move from the bottom; and 2*d*, At a meeting of two or more tides, the sands, &c. frequently accumulate in large banks, which sometimes rise so high as to form the basis of islands. Belgia, the neighbourhood of Alexandria in Egypt, and many other places, are clear proofs of the great and extensive tracts of new land formed at the mouths of great rivers; and the Carses of Gowrie and Stirling in Scotland, are small, but valuable examples of it at home.

Geographers and observing travellers are full of their accounts of new land increasing where great rivers disembogue their waters. What encroachments must not some of the great rivers of Africa and America make upon the borders of the ocean? Some of these have their sources in a thousand hills; and their deep and weighty currents flow several thousand miles in length. But I need not

multiply instances; for this fact, so generally known and acknowledged, is a sufficient proof, that the matter brought down by rivers is not carried out through the bounds of the ocean, and lodged in strata, in order to accomplish a chimerical change.

In the cursory survey which I have taken of the progressive operations and changes on the surface of the globe, we see nothing that either requires or indicates such a catastrophe as the modern philosophy contends for: On the contrary, the result of our inquiries makes it appear evident, that all the change which really happens is by much for the better, and altogether in favour of the present earth on which we live; which shows us that a wise and benevolent Providence superintends and disposes the minutest operations of Nature for good. The high and inaccessible mountains, which are immersed in the clouds, and in the cold and frozen regions of the atmosphere, are penetrated and decomposed by the changes of the air and weather, and washed down by the rains and melted snows; and the matter carried down by the floods is formed into new land, more level, useful, and commodious for man and beast. The coarser grains and hard sandy particles, which swim deepest in the streams, lay the foundation, and the more earthy slime is spread out to enrich the valleys; and it is worthy of remark, that this new land is gradually made, as the progressive ad-

vances of society have occasion for it; and it is made in situations the most commodious for society, viz. in the fat valleys and plains, upon the banks of great rivers, and near the sea; in the midst of plenty, and convenient for increased population; for improvement and increase of the arts, manufactures, and commerce. Many, I had almost said most, of the greatest and wealthiest commercial cities in the world are of this description.

Let us now look a little into the consequences of the superficies of our globe being formed by subsidence in the bed of the ocean, as supposed by the new philosophy. If, then, the rocks and strata which compose the superficies of the globe, were to be formed by subsidence in the bottom of the ocean, we should have nothing but one uniform mass of stony matter, without the appearance of stratum, fissure, or breach of any kind whatsoever. It is necessary and agreeable to the nature of things, that in sediment in water, all particles, of whatever qualities or colours, contained or suspended in the water, must subside next, and be blended through the whole mass. There is not, I think, any thing that can be opposed to this, excepting gravitation; and if we will suppose that the laws of specific gravity take place in this sediment, where it is more likely to take place in perfection than upon any other hypothesis I know; in that case we should expect, that all the metal-

lic and most ponderous stony particles would be sunk lowest down, and the lightest would always be uppermost; but we do not find it so in experience.

Nevertheless, to give the hypothesis all fair play, let us suppose the matter to be spread out in the waters, and to subside in a continued succession of time; and this will only increase the confusion.

The heaviest particles have still the tendency, and they have abundance of time allowed them to sink down lowest, and the next in weight would press hard after them; and others, in their own order of gravity, would follow close upon the heels of the former, which in the end must produce a compound mass, uniform and solid throughout, without the least symptoms of, or inclination towards, any of those horizontal divisions which we call stratification. Upon this hypothesis, we should have no distinct layers or strata; and therefore, of consequence, we should have neither freestone, lime-stone, nor any other of the various strata which now exist; but, instead of this useful variety, all the rocks would be one uniform mass; and in this case, would resemble the largest granite rocks.

Let any man examine a mass of granite, and a hill of granite, which is only a large mass without any bed or division, either horizontal or perpendi-

cular; in which mass or hill, all the grains and particles which compose the granite are entirely commixed, without any order, through the whole body of a small mass, and likewise through the whole body of the mountain. I saw at Ben Nevis, in the Highlands of Scotland, whole mountains of granite, of about twelve hundred yards of perpendicular height, which appears but as one uniform mass of solid stone from top to bottom: and it is out of nature to suppose that rock formed by sediment under the ocean, could be any thing else than an uniform mass throughout, like the granite; and of consequence, upon this hypothesis, we could have no lime-stone, or free-stone, no building stone of any kind, no slate, or marble, or any other curious or valuable stone, for use or ornament; we could have no seams of coal, strata of iron-stone, or any other mine or fossil we now enjoy.

I have already made it evident, that upon this hypothesis we could have no strata or horizontal divisions of any kind; and I am next to show, that there could be no perpendicular fissures or chasms in the superficies of the globe, because, by matter subsiding in water, and continuing constantly under water until the rock be consolidated, there is no opportunity or possibility of any parts of the rock shrinking into less room by the humidity evaporating, or any way draining out of the mass;

for the particles of matter would gradually sink downwards through the water, and insinuate themselves to fill up every cranny and pore in the superficies of the subsiding mass. The water would be gradually excluded, and give place to the heavier particles of matter, and these more ponderous corpuscles would press and adhere closer and closer, gradually and uniformly, by their own gravitating property, and by the equal uniform pressure of the superincumbent weight of the waters, which at once press equally on all parts, and sustain the whole mass equally, so that no part can yield or give way on any hand, as there is no void place or weak side to which it could yield. In extensive pieces of sediment, where water has been drained off by art or accident, the whole mass of such sediment is always found equally whole, smooth, and sound in all parts, without the least aperture or crack, until the water is drained off; and then, when it is no longer pressed and sustained by the incumbent waters, it soon begins to yield on all hands, and to discover chaps and gashes, partly from the loss of humidity, as the water drains out, and partly from the yielding of several parts of the mass towards the lower and weaker sides.

Many of our granite rocks, which were formed by a hasty subsidence, exhibit exactly such a mass, and such superficies, as I suppose, rock formed by subsidence in the waters of the ocean, must neces-

sarily have; with this only difference, that when the granite rocks were really formed by subsidence, they were soon laid dry by the retreating of the tides, and of consequence, they would chap in some places as the moisture was strained out. Accordingly we find there has been such chaps and fissures in the granite rocks, some of which were afterwards filled with foreign heterogeneous stony matter of a different quality, brought by succeeding tides, and some of the fissures and chasms were filled with mineral matter. Such are some of the mines of Cornwall, found in the moor-stone or grey granite; and such are the lead mines of Strontian, in the Highlands of Scotland, &c.

This chapping of the surface of rock, formed by subsidence, must necessarily take place, if it be either alternately wet and dry, by the falling away, and return of the tides, or wholly laid dry by the water entirely retreating from it, while the stony matter retains any humidity before it is perfectly consolidated. But this could not possibly be the case in M. Buffon's change of sea into land, as the advances there would be so very slowly made, and would be accomplished in such prodigious distant periods of time, that the rocks must be as effectually consolidated before they were laid dry, as they would be to eternity; and therefore no room would be left for any change in the superficies of the globe. Nothing in this case would be

found, but one universal sheet of rock covering the whole face of the globe, as solid, uniform, and unbroken, as a sheet of ice covers a pool of water during a hard frost.

Upon reviewing these observations, it evidently appears that there is no occasion for a change of the superficies of our earth, and that in reality no such thing happens. If we manage what we have properly, it will not fail us, but will increase in richness and beauty under our hands. We have seen that the imaginary earth formed by our new philosophers would not answer our purposes at all; and therefore we may safely draw this conclusion from our observations, namely, that blind chance brings about nothing worthy or useful for the emolument of man. The wisdom of omniscient Providence is only adequate to furnish a world for the accommodation of rational creatures. The wisdom of man is unequal to the task of creating or improving worlds, though a thousand Alphonsos should find fault with this, or a thousand Buffons contrive new ones.

CHAP. IV.

OF THE NATURAL HISTORY OF MOUNTAINS; OF THEIR STRUCTURE AND EXTERNAL PHENOMENA.

I now proceed to treat of the natural history of mountains, of their structure, and external phenomena The various phenomena of mountains have greatly puzzled the naturalists of all ages, and some of them have given to the world many absurd and ridiculous conclusions, relating to the natural causes of these phenomena. I confess that the subject is beyond my power to discuss it fully; but as I have spent a considerable portion of my time among the highest mountains in this island, I will set down a number of facts, and make some observations and remarks relating to them, which have not been noticed by others.

In prosecuting this subject, I will,

I. Examine the structure of mountains.

II. I will make some inquiries about the original formation of mountains. And,

III. I will examine and explain the external phenomena of mountains.

I. I AM now, first, to examine the structure of mountains.

I have before mentioned the hill of Ben Nevis, and took notice, that the greatest part of it, and of the contiguous mountains, are composed of fine granite or porphyry. Ben Nevis is about a mile in perpendicular height, and is the king of a magnificent pile or cluster of mountains in the country of Lochaber and shire of Inverness. More than two thirds of the height of this mountain are composed of an elegant red granite. What a treasure would this have been in ancient Egypt, Babylon, or Rome! What a treasure would it now be near London or Paris! Columns and obelisks of any size and height might be cut out here, and the moderns might procure any ornaments they could fancy, as this exceeds every other stone for elegance, beauty, and duration.

I hinted before, that the granite or porphyry of this mountain is one uniform mass, without appearance of strata, division, or fissure of any consideration; and this whole mass of granite is so regular and uniform throughout, that it exhibits not the least mark or indication of strata. But notwithstanding the uniformity of the basis, and the great bulk of this mountain, the summit of it is,

nevertheless, regularly stratified with a different stone, to about one fourth of the whole height: And it is worthy of remark, that, contrary to the bold, but premature assertions of Count Buffon, the hardest rocks in this mountain are the highest. Granite is well known to be a hard stone. There is in a deep gulph at the bottom of a frightful precipice, about five hundred yards on the north-east side of this mountain, a smooth and solid pavement of fine granite; and as a convincing proof of the superior strength and hardness of the strata upon the summit of Ben Nevis, there is below a fragment of several tons weight, which fell from the height of the precipice upon this solid pavement: And as it must have fallen about four hundred yards of perpendicular height, and upon a hard pavement of rock, it is natural to suppose that it would be dashed to pieces by its own weight; but, on the contrary, it is whole and entire. The precipice I mentioned, exhibits a magnificent section of the internal structure of that mountain, in which we distinctly see where the uniform mass of granite ends, and the stratified rock begins above it. We also see, that the strata of different rocks dip towards the south-east with an easy declivity.

In these mountains there are generally fewer breaches and interruptions of the strata, and the declivity is more uniform and regular than in the lowest plains I have examined; and with respect

to the continuation of the same class or assemblage of strata in the line of bearing, I have as yet seen none so regular, or that stretched so far. The rocks appearing bare in many places, by the numberless rivers and rivulets which cut and traverse these mountains in all directions, enabled me thoroughly to investigate the position and bearing of the strata. I have a hundred times traced a particular class or assemblage of strata down the side of one hill in the rivulets, across the river in the bottom, up the rivulets upon the other side of the hollow, and so on for miles, and found them commonly unbroken and regular.

I have, in that country, traced a particular class of strata in that way for near two hundred miles upon the bearing, which is nearly from north-east to south-west, and found both the bearing and declivity surprisingly regular, even more so than ever I observed in any low country for half the extent. It is worthy of remark, that the strata of these lofty mountains, which I have observed to be so very regular, generally decline with an easy slope towards the south-east, and rise towards the north-west, which I suppose was exactly the course or run of the high tides in the chaotic state of the earth, which argument remains in part to be explained; and I have observed in very many places, that this, in general, is the point to which the strata decline or dip all over this island, which is a strong proof of the truth of my History of the

Formation of the Strata, by the flow or stream of water.

There is a great variety of strata, of different qualities, to be seen stretching and declining regularly through these extensive mountains: Such as several species of argillaceous strata, of schistus, and of slate, some of which is exceeding fine; several species of lime-stone, of which there is a great quantity in this country, and some marble; the micaceous mountain rock, and the regularly stratified, hard, granulated, sugar-loaf stone, which was before called a white and light grey quartzy rock, from its being composed chiefly of minute quartzy grains; extensive rocks of mill-stone grit, composed of hard, fine, sharp, and pretty large grains of various colours. This rock is strong, and sufficiently hard, the composition of sharp grains being perfectly well cemented: It is very regularly stratified, and would rise in beds of any thickness and of any size. In short, this rock only wants to be known to be a valuable acquisition to society for mill-stones. I saw this rock by the sea-side at Lochbroom, upon the south side of the Forest of Coygach: I also saw it upon the south side of the Salt-Lake, or arm of the sea which separates Arasaig from Moydart. Besides these mentioned, there are other stratified rocks in these mountains; but this is a sufficient specimen of the regular strata. There are also extensive rocks of granite and breccia, which are not strati-

fied. Although the granites and breccia are not generally stratified in this part of the Highlands, they nevertheless preserve the same course of bearing as the other strata; I cannot say regularly, but rather irregularly. They are indeed as regular as any perfect strata in the line to which they trend; but they are not regular in that line, as they are frequently thicker and thinner; sometimes swelling to the magnitude and height of a mountain, and a mile or two forward dwindling away almost to nothing.

I THINK I have been sufficiently explicit in explaining the structure of mountains, and have made it abundantly evident, that however rugged and unequal their appearance is without, all is fair and regular within; which at once knocks on the head the idea of ruins, and likewise of internal inflations, and other whimsical accounts of their formation. There are as clear, distinct, and unquestionable marks of the mountains being formed and stratified by the motion of the tides, as of any of the valleys or coal countries.

II. I SHALL now make some inquiries about the original formation of mountains. When I explained the history of the formation of the strata in the superficies of the globe, in my second general head, it then appeared to me very evidently from all the phenomena, that there must have been

monstrous high tides at that period; and that it was impossible to explain these phenomena without them. Having since perused the Chapter on Tides in Mr Ferguson's Astronomy, I find in it a clear and perfect illustration of this great point. According to his scheme of the tides (upon the supposition of the earth being a fluid globe), it evidently appears that the tides actually did rise several miles higher than the highest mountains in the world, when this globe was in a chaotic state, before the business of forming the mountains and the strata was completed.

When this globe was in a fluid chaotic state, it appears to me more than probable, that the tides, in following the sun and moon, would then be highest upon the two opposite parts of the globe, which are now the two continents; that the tide did not gradually and uniformly follow the moon westward, as the earth turned eastward upon its own axis in the diurnal motion, so as to be equally high upon every part of this globe, which was in every moment of time opposite to the moon, but that it advanced in great swells, and that each swell would, by its own weight and force, advance a little before the attracting force of the sun and moon, which would bring the power of attraction to act the contrary way for a short space of time, which of consequence would bring the tide to stand at a height upon two opposite parts of the globe for a short space of time: And that before

the powers of attraction would begin again to bring the fluid to a motion westward, this globe would be advanced so far east, that the powers of attraction would act so forcibly, as to cause another great swell of the tide, and so on. Now, if we will allow these opposite resting places of the tides to be the two continents, the old and the new, we then have what we wanted, to enable us to account rationally for the phenomena of the superficies of our globe. In this view of the subject, my former account of the sea purging itself upon the land, by the motion and force of the tides, receives new light and strength.

The tides would not move round gradually and smoothly; but when any given parallel of the globe was so far advanced eastward during the height of the tide, the moon's attraction would fail to act where the tide was at the height, and would act in its greatest force further west, which would cause the tide to rush from that height after the powers of attraction. Our trifling tides now do not move with such smooth uniformity.

If it be allowed that the two continents were the quarters of the globe where it always was high water, at the end of a little more than every twelve hours, it of consequence must be allowed that the tides ran without stopping through the two oceans in the intermediate space of time; and when the tides in the chaotic state of the earth once attained their highest pitch upon the two continents, as

I observed before, they would stand still without rising or falling any thing material for some space of time, and that always at high water; during which suspension of the tides, the earthy matter would subside plentifully upon those two quarters of the globe; and if, as I have supposed, the tides continued to run all the while in the two oceans, during the high water in those two quarters, the earthy matter, being carried forward by the waters there with a rapid motion, could not subside so plentifully in the oceans as upon the continents, where the waters came to a stand for some time at the height of each tide. In this view of the subject, it appears, that the earthy matter would subside and be spread out by the motions of the tides, in such quantities upon the two continents, that it would be so much exhausted upon the land, that there would not be a sufficiency left mixed with the waters to raise the bed of the ocean as high as the land, when the height and force of the tides began to abate, upon the emerging of the firm land, and contracting the fluid superficies into less room.

I showed before, that the strata and unstratified rocks were formed by water, in different degrees of motion and rest, or in other words, by the tides running, and at the height; and if the tides were always highest upon the two continents, it is easy to conceive how the land happens to be so much higher than the bed of the ocean. If the tides

rose in the chaotic state of the earth to the height supposed by Mr Ferguson, it is easy to account for the great height of the highest mountains, as the tides then rose much higher than the highest of them.

When this planet was in the chaotic state supposed, the tides would rise in a line from north to south, or thereby, and these tides would be highest at the equatorial parts, and they would diminish in height gradually, as the line receded from the equator towards the poles. It is natural to suppose, that as the tides were highest in the equatorial parts of the globe, agreeable to Mr Ferguson's scheme, so would they run foremost there, and the line of the tide would recede a little backwards towards the east, upon both sides of the equator. Upon this supposition of the line of the tides, the course or bearing of the strata in the equatorial parts of the globe should be true north and south; and as the strata advance from the equator towards the poles, this line should lean back towards the east on both sides. It is said that they trend north and south at the equator; and I am confident it must be so. In our latitudes, the line of bearing of the strata is as true to this supposed line of the tide as can be imagined, which is nearly north-east, or between that and north north-east.

If the tides were then highest at the equatorial parts, the highest mountains should be there also;

and accordingly it is there we find them. Our mountains in these northern regions are but diminutive, in comparison to the Cordilleras in South America, and others between the tropics; and if the greatest, middling, and lowest heights of all the principal mountains in the world, and the latitudes they are found in, were examined and compared with this scheme of the tides, we shall find them correspond with it as near as could be desired or expected. Indeed, we shall find a beautiful agreement and correspondence in all the phenomena of nature, if we will but take the trouble to investigate them upon the principles of nature and truth.

I hope I have now removed all difficulties out of the way, in accounting for the great height of many of our mountains, above the level of the sea, and of the champaign countries. The highest tides would first lodge the granite mountains as a foundation, and future tides, not quite so high, would form the strata, which in some places we find riding above the highest granite rocks, and in others running parallel with them.

It is proper to observe here, that it appears to me more than probable, that many of the great ranges and clusters of mountains were formed at first in a great plain above, and were afterwards cut through and furrowed; which I will explain in my next general head of this history of mountains. There is one very material circumstance

which I have frequently observed, and which greatly strengthens this opinion. I hinted before, that I have traced the same range of strata through several hollows, and over several mountains in the Highlands. In the course of which investigation, I have frequently traced the same individual stratum, and a number of strata, from the deepest gulph or hollow, up to the summit of the mountains on both sides of the hollow; and where a river cut right across the strata, I could see perhaps several hundreds of them ascending gradually on both sides, with an easy acclivity from the bottom quite up to the tops of the hills.

The extensive countries of Abyssinia, Tartary, and New Grenada, are all of them a great height above the level of the sea; which appears to me as instances of such high land, but not cut through to make mountains of. Where we find an extensive elevated plain in any part of the world, such as new Grenada and Abyssinia, we may suppose that the tides fell so low, as not to overflow these plains soon after they were formed, by which means they have not been cut through and furrowed like the mountains, by forcible tides frequently running over them; whereas, on the contrary, where we see ranges of mountains dreadfully ploughed and trenched, with deep glens and horrible gulphs and excavations, it is certain that weighty and powerful tides have repeat-

edly run over them for a considerable space of time.

III. I WILL now proceed to examine the external phenomena of mountains, and of their excavations.

I have clearly proved and illustrated one important point towards understanding and explaining such phenomena of nature as appear upon the external surface of the globe, viz. that in the chaotic state of the earth, the tides rose to a surprising height, and were greatly agitated from their own weight, and the violence of their motion, with sometimes the addition of strong winds; and consequently stony matter, carried by water in such a degree of agitation, must be lodged in unequal cumulations. I must not here be understood to mean that the mountains were lodged by the tides at first, as they now appear. I will presently make it evident, that they owe many of their present phenomena to some future operations, I might call it future depredations. What I mean at present is this, that the tides, while in full height, in their motion from east to west, lodged the stony matter upon what began to be the solid superficies of the globe, in parcels or cumulations of different degrees of height and extent.

There are mountains of granite in the Highlands of Scotland, and many other parts of the world, of great height and extent, in which there

is no vestige that should indicate their having subsided at different times; the whole mountain being one uniform mass. It appears to me, that the work of forming rocks by subsidence would be performed in a short time, in the course of a very few tides; but, on the contrary, that the stratification of the superficies of the globe was a more leisurely operation, which would require much longer time, and a great many succeeding tides. Moreover, the stony matter of which the granite and other subsided rocks are composed, is such, that if ever the tide ceased in the least from the full force and rapidity of its forward motion, we would expect that a great quantity of it should subside at once, as this rock is composed of large grains of a ponderous quality, some of which are so large, that they may be called fragments; and it is the property of such ponderous grains and fragments, to subside suddenly in water, at any degree of rest.

When the tides rose so very high, they would of consequence fall proportionally very low, so that we may say that the foundations of the mountains would be seen; and when the waters, at the ebbing of every tide, began to fall away from the summits and sides of the mountains and higher grounds, the moisture which remained mixed with the newly subsided or stratified matter, would ooze, or strain out, copiously at first; and this water filtering and straining out of the humid super-

ficies, would soon collect into small streams, and these streamlets would wear furrows in the yet soft and humid surface, especially when assisted by the weight and force of succeeding tides.

Many of these small streams would collect and form a rivulet, and many rivulets uniting their currents would become a river. It is easy to conceive that all these streams, especially when collected into rivulets, would at first wear their several channels very fast, and that much of the newly subsided matter would be carried down the several rivers, most of which would be lodged far down, and this would be removed by future tides, and disposed of in strata. I have seen between some tides, at the sea-side, deep gutters worn by the water filtering out of the mud and sand, and the higher and larger the heaps were accumulated, always the deeper the gutters; and it is probable in the highest degree, on an accurate survey, we shall find this observation hold good in the great as well as in little. The higher the mountains, generally, the deeper the glens and gullies in proportion.

I observed before, that the lesser streams and rivulets collecting together composed rivers. These rivers would still follow the great waters of the ocean in the retreat of the tides, and the weight and force of the rivers would soon wear channels deep enough to contain them, as they advanced after the great waters down the hills and through

the plains. This appears to me to be the true origin of rivers; and the rains which fall upon the earth from time to time, and in greater quantity upon the higher than upon the lower grounds, still replenish their channels, and enable them to continue their courses.

There are yet many external phenomena of mountains which deserve to be examined and explained. There are among several mountains a great number of gulfs and chasms, romantic precipices, gashes and irregularities, in rocky countries, which are not now the beds of rivers, or of rivulets, but are perfectly dry; and I have seen the opposite sides of some hills resembling one another so exactly, that they appeared as if they had been cleft asunder by some convulsion of the earth. I have met with some who assert, not only that such hills parted from those upon the opposite side of them, but also that several known islands were by violent concussions thrown off from the opposite lands, and that the sounds between them were made by these accidents.

With respect to such gulfs and chasms among rocks and mountains, as mentioned above, although they may now be dry, yet nevertheless water has been there. Some mighty current, rush, or eddy of the tide, before the ocean was settled in its present bed, undermined, scooped out, and formed these irregularities at first. I have examined the supposititious twin sides of mountains, and in ma-

ny instances have found no supposed breach or separation: But I have observed the same slope or declivity perfectly whole and regular, without breach or fracture, which makes it clear to a demonstration, that such hills had suffered no such separation or convulsion; but, on the contrary, that they stood as firm as ever where they were first formed, and that the gulf betwixt them must have been scooped out by some strong current of water, before the induration of the strata was completed, and the tides fully subsided. I have carefully examined many such places, and every where found these observations hold good; and I am confident, that the notion of islands falling off from the main is an error, a hasty conclusion of the same kind; and that the same real and natural cause produced both these effects, viz. a strong current or run of water, which cut a passage betwixt the island and the main, and betwixt the two correspondent sides of the mountains.

All the little examples of revolutions, or violent concussions, which we have occasion to see, such as earthquakes, the undermining of rivers, and of the sea, &c. are so inconsiderable and trifling, that they give no sanction to this rash hypothesis; and, moreover, what falls off or is broken and disturbed in these little instances, is always broken into confused fragments, or crumbled down to an entire rubbish.

It is reasonable to suppose, that in the raw and

humid state of the earth, at first, a great quantity of a mixed vapour would ascend by exhalation, which would disturb the elements, and raise strong and violent winds; these winds would superadd an additional force to the high tides, even after the mountains were formed; which tides, at any rate, were exceeding strong and violent when they rose to such an amazing height. I have observed, I believe more than once, in the course of these inquiries, that there is an exact agreement and correspondence in all the phenomena of Nature, by which they are naturally explained and illustrated, if we had but the attention and skill to discover and make proper use of this connection and agreement. I am going just now to produce a very remarkable instance in point, which will throw some light upon the external phenomena of mountains, and make the explanation of them more plain and perspicuous.

Every observing person must have frequently seen in plains, at a little distance from large and high mountains, a prodigious quantity of coarser and finer gravel, some of it containing large boulders, and water-rounded bullets of all sizes mixed with smaller gravel. This beachy gravel is often found spread out with a plane superficies, and as often accumulated into long, round, oval, or semi-circular hillocks of lesser or greater height and magnitude, and some of them so large that they may be called little hills.

I will point out a few of the many places where I have seen this gravel in Scotland.

There is a great quantity of it in the neighbourhoods of Brora and Dornoch in Sutherland, as also in the neighbourhood of Balnagown, and between Dingwall and Beauly, in Ross-shire; all round Inverness, where there are pretty high hills of gravel; and all the way between Inverness and Nairn, and at Fort George. There are large hills of gravel about Forres in Moray, in which there is a vast quantity of large bullets, and it continues to appear in hillocks, all the way between Forres and Elgin, and all the way between Elgin and the river Spey at Fochabers. There is a great quantity of it in the country of Monteith, and in a great many places, and in great quantities, in that long stretch through Perthshire, Angus-shire, and the Mearns, all the way between Monteith and Stonehaven. There is also a considerable quantity of it between Moffat and Dumfries, and between Dumfries and Thornhill in Nithsdale. But of all the countries I have yet seen, the most amazing quantities of this gravel are found in the shires of Inverness, Nairn, and Moray, which lie directly to the eastward of the great run, or gulf, which stretches or cuts through the mountains from the west to the eastern coast, by Fortwilliam and Inverness.

It is very evident that this immensity of rounded stones and gravel is all of it the spoils of the

mountains, torn by the force of water out of the numberless glens and gulfs, and other excavations of the mountains; and that the stony fragments torn by the violence of water off the superficies of the rocks in these mountains, was afterwards carried through the hills, and after being tossed and rolled by the violent force of the water in so long a course, until it was rounded and worn; like what we see upon the sea-beach, it was at last lodged by the water in the countries where we now see it. The greatness of the quantities found in those countries sufficiently proves the source from whence it came. We may, upon the same principle, account for most of the phenomena we meet with upon the face of the globe. If we have recourse to water, the solution of the phenomena will be natural and easy; but, on the contrary, if we refuse its agency, we shall be left in the dark, to doubt and conjecture without end.

If we consider the numerous glens that are made, the lakes and gulfs that are scooped out, and the runs that are cut through these mountains, from sea to sea, we are obliged to suppose, that the quantities torn off the superficies of the strata was even still more than the beds and hills of gravel can account for. Great and extensive as those are, they do not correspond with the excavations of the mountains; and we are not left to look for it all in the gravel beds. We see a much larger

deposition of it than the accumulated gravel, where it is much better disposed of.

The beds and hillocks of gravel are a great nuisance. Nothing but dry sterility reigns where they are; and had all the spoils of the mountains been spread upon the plains, the plains and valleys would not, as now, have been the scenes of the wealth and pleasure of man; every low field and valley of them had been all covered with bullets and gravel. But happily for us, the greatest part of this nuisance is disposed of in rock; strata I cannot call it, as the coarse sort, which differs nothing in appearance from the hills of gravel, is not stratified. The only material difference between the one and the other, I mean between the coarser breccia or pudding-rocks, and the coarser gravel hills, is, that the former bears its proportion of the solid bulk of the globe, and is cemented and indurated to a high degree.

In order to give a further idea of the proportion between the matter scooped out of these mountains, and the repositories where it is lodged, I will point out a few of the places where I have seen most of this rock in Scotland.

There are extensive rocks and high cliffs of the breccia or pudding-stone upon the south shore at the west end of the Pentland Frith, to the westward of Thurso in Caithness, which stretch quite across the county of Caithness into Sutherland; and in Sutherland as well as Caithness, this rock

is of a rough contexture, and appears in pretty high hills, deep glens, overhanging rocks, and frightful precipices, to the west of Brora, Dunrobin, and Dornoch, which give a grotesque and formidable appearance to that country. This range of breccia stretches also quite through Sutherland, and likewise through Ross-shire, the west side of Ferndonald, and Dingwall, where it exhibits the same phenomena as in Sutherland and Caithness.

This range of pudding-rocks still continues the longitudinal line of bearing, which is nearly from north-east to south-west, quite through Inverness and Perth shires. It appears in considerable hills, and very high and rugged rocks, upon both sides of Loch Ness; and stretching through the mountains of Stratherig into Badenoch, forms a remarkable precipice, called *Craigdow*, or the *Black Rock*. The same range of rocks is seen further towards the south-west, in several places to the south of the Black Mount, and in the country of Glenorchy in Argyleshire. I suppose that the longitudinal line of this rock, so far as I have pointed it out, is little less than two hundred miles, and in some places not less than eight or ten miles, across the line of bearing.

The next range of the breccia which I have yet seen, is situated above sixty miles further east than the one above mentioned. It emerges from the sea at Troop-Head, upon the south side of the Mo-

ray Frith, and stretches through Aberdeen, Mearns, Angus, and Perth shires, keeping principally the north-west side of Strathmore, immediately under the south-east side of the Grampian mountains, though sometimes it strides across the beautiful valley of Strathmore, and is found upon the south side of it, as at Kinfauns below Perth, &c. This remarkable rock stretches through Perthshire into Stirlingshire, through the country of Monteith into Dunbartonshire. It crosses the river Clyde near Dumbarton, and reaches into the west side of Airshire, where it enters the Frith of Clyde. This range of breccia exhibits in many places the same phenomena as the first described; and in other places in this long stretch, it is found of a finer contexture, and composed of smaller gravel, when it assumes a stratified form. I am not sure that this course of the breccia is not still of greater length and breadth than the first. There is also a considerable quantity of this rock found in the countries of Annandale and Nithsdale, particularly in the neighbourhood of Dumfries, between Dumfries and Moffat, and between Dumfries and Thornhill, &c.

The pudding-rocks found in the Highlands and north of Scotland are so very extensive, that when joined by the hillocks and beds of loose bullets and gravel in those countries, I doubt if the excavations of the Highland mountains to the westward would be sufficient to supply the prodigious

quantity requisite for composing these rocks and accumulations of gravel. I am confident, that a considerable part of the composition was carried through the Highlands from the Western Isles.

I see many indications of the islands upon the west and north of Scotland having been at first joined to the main, and of their being afterwards separated from it, and from one another, by the force and weight of future tides. The strata in the Western Islands of Scotland are remarkably flat and regular. Some of these strata stretch from one island to another, and still preserve the same course and declivity in both; and the regular strata, in some places, stretch from the main land to the islands, and in other places from the islands to the main land. I observed before, that the position of the strata in the Highlands upon the west coast, is in general very regular and moderately flat, as well as in the Western Isles; and from many sites in that country, a great number of the isles still appear all as one land with the main; but upon shifting the station, we discover the sounds that part them asunder. The mountains in the isles of Skye and Rum are rather higher than those upon the main near the coast, and the same may be observed of the island of Jura, and some others; and it is remarkable, that the weighty and rapid tides which cut the islands off from the main, and ploughed the deep channels that divide them from one another, made very great impression upon the

west coast of the main land. This observation is evident from the great number of friths, sinuses, or arms of the sea, which every where cut and indent the west coast.

It deserves to be noticed, that a considerable river runs into the head of every one of these canals or lochs, as they are called; and I believe it holds every where, that the larger the river, the longer the salt canal; which suggests the idea, that the first advances of a mighty stream tide entering the channels which these rivers had begun, in the tender and newly formed strata, would easily, by its prodigious weight and force, plough up the bottom of the channel to a great depth; and so make room for succeeding tides to form such channels, fit for the salt water lakes which they now contain. And it is very probable, that some lesser or greater streams of water, beginning channels in several places, would first give entrance to the tides which cut asunder the isles from one another, and from the main. It is also remarkably to the point in this investigation, that the tides in the period I mention, were very near making a great many more islands upon the west coast of Scotland, as there are many places where only a very small neck or isthmus separates the heads of two of these lakes, and prevents them from running into one another, and of forming an island; such, for instance, is the narrow isthmus at West Tarbet in Argyleshire, not above a mile over.

I have heard it observed, that the mountains of Britain and other countries stretch from east to west; but I suspect that this is only a hasty conclusion from a cursory view. We know with certainty, that the longitudinal bearing of the strata is from north to south, or to the west of south; which was the exact line of the tide, and the tide was the efficient cause of the disposition of the strata. We have seen also that the declivity of the strata in general is towards the east or south-east, and that they rise and crop out towards the north-west, excepting in such low places where there might have been an eddy of the tide, or where it must of necessity have turned in, or backward towards the land, from some neighbouring sea, after the tides began to abate. Now, from the disposition of the strata, we ought to find ranges of mountains stretching from north to south, or to the westward of south; and I suppose, if we examine the matter a-right, we shall find it so in Britain. It is much longer from Thurso in Caithness to the Mull of Galloway, than from Aberdeenshire to the west coast of the Highlands, and the mountains of Galloway are not the last links in the chain from north to south. They reach all the way through Cumberland, &c. to the south side of Wales, with no other interruptions than what have been cut through and widened by the tides rushing down upon the land from the Atlantic ocean.. It is true, that many single mountains in a chain, appear in ridges from east

to west; but it is plain and easily conceived, that these ridges would be formed by the running of the high tides after the strata were deposited.

I have mentioned more than once, that in general the strata dip towards the east, and rise towards the west; and I will now observe, that it is this position of the strata that was the occasion or natural cause of the many abruptions of mountains to the west in this country; and many of these abrupt precipices will occur in all countries under like circumstances as with us, and not otherwise. But some of the strata upon the west coast of the Highlands, and in the contiguous isles, appear evidently to have been formed by the tides in their return from the Western Ocean, as hinted before, after they were fallen so low, that they could not run over the continents of Asia and Europe, but could only swell the ocean to a monstrous height as they advanced westward. The indications I observed of those strata being formed in this state and course of the tides, is their dipping towards the west, contrary to the general dip at a distance from the coast; and that these strata, which have the western declivity, are not of the same quality and texture as most of the mountain rocks, but are many of them more like our gritstones, freestones, and the basalts, which I suppose were among the last that took their

form and station in the wise disposition of all the parts of this stupendous fabric.

CHAP. V.

OF THE COMPONENT PARTS OF ROCKS.

I NOW proceed to examine the nature, quality, size, and figure of the larger grains and fragments found in the composition of our rocks and strata.

In the prosecution of this branch of my inquiries, I will especially examine such parts or ingredients found in the composition of the rocks and strata as are most singular and remarkable; and the first I will take notice of is *talc*.

1. TALC is a singular fossil body. We have no such thing as whole strata of talc; nevertheless, we meet with great quantities of it upon the surface of the earth: in the composition of the strata, we frequently meet with it in large fragments, imbedded in several stratified mountain rocks. It is a considerable ingredient in the composition of granite, and more especially of the white granite. We find that it is a considerable article in the

composition of slate, of several species of schistus, and many other argillaceous strata.

The white and the grey broad-bedded mountain lime-stones contain a considerable quantity of it. We sometimes see it in the basalts, frequently in freestone, and I have seen it in lead ore, and other mineral substances: But it is most abundant in the micaceous mountain rock, where we see it in such profusion, that I am persuaded it constitutes one third of the whole composition of some varieties of that stone, which in a clear day gives the whole rock a bright metallic appearance *.

The fragments of talc appear to have no relation to the form and structure of the stone, but rather to be accidentally taken up into the composition, as they lie promiscuously in the stone, without any form or order whatever.

It appears to me highly probable, from the tough flexible quality of the talc, and from the figure of its parts or particles when broken down to mica, resembling the scales of fishes, that the mica is a valuable ingredient in the composition of such strata as are broad-bedded, and of a tough cohesive quality, such as slates, flags, &c. It is not at all improbable, that without mica, we should

* The mineral substance here described under the name of *talc* is mica; and the micaceous mountain rock is probably, from the description, granite.—EDITOR.

have had no slate or other stones of a strong cohesive quality, which are exceeding useful and necessary for many purposes. On the contrary, our hard stones would have been brittle, and would have broken into angular glebes, which would have made them very unfit for the purposes to which they are applied.

2. The quartz is equally plenteous and useful in the composition of our rocks.

Pure quartz, or feldspar, is perhaps as curious a fossil as the talc. It is true, there is a species of coarse quartzy rock in the Highlands of Scotland disposed in regular strata; but all those strata are evidently composed of fine grains of the pure quartz broken small, as is evident by examining their texture. Whereas, some species of the purer quartz, as it is found in the strata, have no visible grain or texture at all, but are pure, pellucid, and uniform throughout each grain, and there is one species of it, called *feldspar*, which exhibits a finely tabulated texture.

I will, in the first place, take a little notice of the tabulated species, of which there does not appear quite so much as of the uniform; and then I will take a view of the other species, which appears to be more widely and generally diffused in the composition of the strata, and over the face of the earth. The greatest quantity of the tabulated quartz, or feldspar, is found in the composition of

some of our granite rocks, and upon the face of the earth in granite gravel, in places where that stone has been decomposed.

Our granite rocks are chiefly composed of quartz, schorl, and mica*. Some of the white granite seems to contain little else besides quartz, or feldspar and mica, and to have little or no schorl in the composition. The quartz found in the granite appears either in grains or fragments, and these grains and fragments are of various colours, though chiefly red and white, and the several shades and varieties of these two principal colours.

It is when the granites are exposed to weather and decompose, that we can discern what they are chiefly composed of; and in this wasted state of it we see very evidently, that the quartz it contains is in grains and fragments, of various sizes and shapes, as well as of various colours. I have frequently seen grains or masses of feldspar in the decomposition, and in the sections of a mass of granite, so large that they might properly be called fragments. These fragments are of various sizes, and they are commonly of a cubical, a quadrilateral, or a rhomboidal figure, with sharp angles; and these are commonly seen from the

* The Author has confounded quartz and feldspar, which are totally different. The component parts of true granite are quartz, feldspar, and mica.—EDITOR.

eighth part of an inch, up to two inches and more in length.

These fragments of quartz in granite are all hard and fine, of a pure crystalline quality, and they are evidently of a laminated or a tabulated texture, resembling some of our mineral spars, only that the quartzy grains are much finer, and more hard and compact than the tabulated spars.

The grain and texture are not the only thing remarkable of these masses of quartz; their cubic and rhomboidal figures also deserve our notice, and to me they have every appearance of being broken off from some original strata; which strata are no where to be found in this world; and yet the quantity of this species of quartz contained in our granite rocks is immense.

The quantity of the other species of quartz, which are found in pure pellucid granules of various sizes and colours, and of no visible grain or texture, but which appear uniform and homogeneous throughout, is still more immense than that which is of a tabulated structure.

I will note here, that the word *quartz* is only an improper name given by me to multitudes of fine grains of various colours, sizes, and qualities, to save time. A proper history of them would fill a large book. Many of them are real gems, and most of them perfectly fine and pellucid. I observed above, that these grains are of various sizes and colours. I found a most beautiful purple-co-

loured sand upon the north shore of the Moray Frith, in such quantity as to colour the shore in some places, so as to attract my eye from afar. The grains of it were much larger than common sand. I gathered some of it; and upon examination, every grain of it was found to be pure amethyst. I afterwards discovered from whence it came, and saw some of it in the composition of very large stones, upon the banks of the river Allgrade in Ross-shire, a few miles up the river. I then purposed to return and make a further search, to see if larger pieces of so fine a stone could be found among the rocks higher up upon the banks of that river, but I never after had a proper opportunity. There are various grains of several other colours found in the composition of many rocks, and all of them as fine as the amethystine sand now mentioned; but it would be too tedious to enter into minute disquisitions of this kind. Therefore I will take a general view of the most common quartzy grains, which are of a white or whitish colour; and these are the principal materials in the composition of the greatest number of our rocks and strata.

The granite rocks are chiefly composed of grains of quartz of various sizes and colours. The sandstones and gritsones are evidently a composition; and grains of quartz are as evidently the prevailing material in the compound. With the gritstones may be ranked some of the coarser-grained mill-

stone grits, and part of the finer breccia, as being composed of much the same materials; the principal part of which is fine, pellucid, water-rounded stones of various sizes and colours, for each of these grains is a real, distinct, and a perfect stone. The roughest and sharpest mill-stone grits frequently contain garnets, and many large pellucid granules of other equally fine stones of different colours. All the sand-stones, and others which contain larger or smaller grains of quartz, are to me equally as mysterious as the talc. There are no strata in the world from which these several coloured grains could be broken off, and with which they may be now compared and referred to as their origin. The granite rocks are immense. The quantity of rough gritstones, containing pretty large, fine, and hard pellucid granules of various colours, is very considerable: and of the sand-stones, white, red, and grey, the quantity is also great. Add to these the basalts, and all other rocks containing hard grains of quartzy matter, with the loose sands in the desarts of Arabia, of Barca, and all the other great sands in the world, of which we have small samples in miniature at home, especially in the north of Scotland. Now, when we throw all these together, what a prodigious bulk will it swell to! It is still of much greater magnitude than the mica, though we find this too as widely diffused. The grains of sand have long ago been examined by the curious, and they are

all found to be fine, hard, pellucid stones, having their asperities and sharp angles worn off by attrition against one another in water. I now proceed,

3. To examine the schorl, which is another curious ingredient in the composition of many of our rocks and strata. It derives this name from the Germans. Our British naturalists call it *shirl*; and I think it is called *cockle* by English miners; or rather, cockle is the name they give to basalts and other stones in which grains of schorl prevail. Schorl is a hard and heavy substance, of a shining jet black, and of a glassy appearance when found in large grains. The larger grains of it appear to be of a finely tabulated texture, the plates or laminæ of which are very thin and fine, but adhering close together, so as not to be of a loose foliated structure like talc.

This curious fossil is found generally in a dispersed state, in grains of different sizes, in the composition of most of the granites, in all the basalts, and many other rocks, especially such as are of a granulated texture, and of a black or dark grey colour. Although this stony substance is hard and heavy, yet I am persuaded that it is more fragile than the quartz; and my greatest reason for alleging its greater frangibility, is this, that I have not seen so many large grains or fragments of it as of the quartz. The largest grains of schorl that I

have seen, did not exceed half an inch over any way; whereas I have frequently seen fragments of the tabulated quartz or feldspar above two inches the longest way of the mass. I have seen, in several parts of the Highlands, a species of granite more black than common, much weathered, and in a state of decomposition; and in the debris of the disunited mass, I could sometimes discern that more than one half of it was schorl, and the remainder was mostly quartz.

Now, the schorl deserves our attention as well as the quartz and mica. We have no strata of the one more than of the other, and yet the schorl also has evident marks of being the ruins of some ancient original strata, of which there are none now to be found; and if there were, it might be a very proper question, How came those strata to be broken to pieces, and the fragments of them to be diffused so widely as we find them in a dispersed state in the composition of our prevailing strata? That the most of our rocks and strata are composed of grains and particles of various qualities and colours, is obvious to the slightest observer. We can hardly cast an eye upon one of our common building stones, without seeing this observation verified. It appears, then, that although mica, quartz, and schorl, are the principal parts in the composition of those rocks, they, notwithstanding, did not originally belong to them. In the course of my inquiries into these matters, I perceive that

these remarkable ingredients in the composition of our rocks are inconceivably finer than the rocks which they compose. They have a form and texture of their own, distinct from the form and texture of the rocks; and there are no rocks of the same quality and characters as these grains. Our rocks are evidently composed of various different grains of divers colours, qualities, and figures; whereas, on the contrary, these grains have no visible particles; there is no appearance of a composition, but a perfect homogeneity is found in all of them. There is indeed some little resemblance between the form and structure of some of the largest masses of these and the finest of our laminated strata.

The talc and tabulated feldspar are evidently stratified as well as our slates, coal metals, and others, but there is a thousand times more disparity between the fabrication of their several textures, than there is between the coarsest hair-cloth and the finest silk or cambric. The similitude between them is just sufficient to show us, that water was the agent in the formation of both. There is a homogeneity, a beauty, an uniformity, a fineness in the essential corpuscles and textures of these several fossil substances, which suggests to us, that these are fragments and remains of strata, which were created by the Almighty in the first formation of all things. The present state and appearance of our strata clearly point out to us, that the

strata which formed the superficies of the globe at the first creation, have been somehow or other broken to pieces; and that the present superficies of our globe is composed of the fragments of the ancient strata. But before I enter fully into this consideration, I will just hint at a few other substances found in the composition of our strata, in order to place them in a proper point of view.

Remains of the testaceous tribes, of coral, and other marine productions, have long ago been advanced as proofs of an universal deluge, and they are so. At the same time, I am sensible that a very indiscreet and unmechanical use has been made of such proofs, to countenance and support a lame hypothesis. The evidence of our senses, and the most acurate experiments, prove these to be real shells, and real corals, &c. and no *lusus naturæ;* and therefore, although the earth should be covered with water a thousand times over, these various shells, &c. could never enter into the body and composition of the solid rocks and strata, without the whole of the matter composing such strata, shells, coral, and all, being blended with the water in a chaotic state. All the species of shells found out of the strata are also found in them; and I have seen them in some places exceeding numerous, even up to near one half of the whole matter composing the stone; and moreover, I have seen them in such abundance in a pit upon the sea-shore, sunk a hundred and thirty

feet below flood mark. Besides the numerous animal and vegetable spoils of the ocean found in the strata, there have also been frequent discoveries made of their containing numerous specimens of almost all the animal and vegetable tribes found upon the face of the earth.

Many weak and fanciful methods have been employed to account for these phenomena, without having recourse to the universal deluge; but I will say in one word, that it is morally impossible to give any account of them, that is not liable to many weighty objections, and that does not infer many absurdities, without having recourse to the deluge, or to the chaotic state of the terraqueous globe, which I hint at, and which is really the same thing.

If I am allowed to suppose, that the quartz, schorl, and mica, with all the fine and beautiful grains in the composition and decomposition of our rocks, were once fair and regular strata; that these ancient strata were somehow or other dislocated, broken to pieces, and mixed with the waters of the ocean; that the waters of the ocean, or the terraqueous globe, were raised partly by natural and partly by extraordinary causes to monstrous high tides; that the ruins of the antediluvian strata were taken up and agitated by these high tides, until they were mixed with the waters in a chaotic state; and that this chaos was agitated and carried forward from east to west by the

force and violence of those tides, until, by trituration and grinding against one another, the fragments of the ancient strata were broken to pieces, and ground down into the grains and small fragments we behold, which were afterwards formed into our rocks and strata, after the violence of the first great tides began to abate, as I described in the second head of these inquiries. Now, if it be allowed, that this account of the matter is just and natural, then we can dispose of all the materials which I have collected to the best of purposes. A ray of light then shines upon this dark and difficult subject, to show naturalists the right path, and a foundation is laid, and every difficulty removed out of the way of the future study of the mineral kingdom; so that this branch of natural history may, and I am persuaded that it will, in time become as easy, as pleasant, and as determinate a study as either of the other kingdoms of Nature.

CHAP. VI.

OF THE PROOFS OF THE UNIVERSAL DELUGE, DERIVED FROM THE STRATA OF COAL, AND THE GENERAL APPEARANCE OF THE SURFACE OF THE GLOBE.

THOUGH I have reserved the strata of coal, and its concomitant strata, for the last proof of the deluge, yet I do not reckon it the least important and decisive. The strata of coal may be placed among the unquestionable proofs of that great catastrophe.

My former disquisitions make it evident, that the strata which compose the superficies of our globe were formed by water. Now, if it be acknowledged, that the superficies of our globe was formed by water, I think it is necessary, either to allow of my account of these matters, or to embrace Count Buffon's hypothesis; but I have shown, that the real structure of the superficies of our globe is absolutely inconsistent with this hypothesis. I am persuaded, from the little I have seen and been able to investigate, that when all the phenomena of the strata, and of the mineral kingdom in general, come to be candidly and seriously examined, they will be found to point out, not

a probability only, but even the necessity of acknowledging the universal deluge, and such a deluge as I have suggested.

But I will leave many of these phenomena to be examined by others, and will proceed to take the coal under immediate consideration: And I believe it is out of my power, and out of the power of any other man in the world, to produce a more decisive proof of the universal deluge than our pit-coal; and also of the wisdom and benevolence of the Supreme Being, in over-ruling the events and operations of Nature, and bringing about the good of man by that extraordinary revolution.

It appears to me past a doubt, that timber was the origin and principal matter of which coal was composed; and if we allow the origin of coal to be timber, it is impossible to give any rational account of the form and situation of the strata of coal, without admitting the doctrine of the deluge to be true. That coal was composed of timber, is in some measure evident to our senses. I have seen the grain and figure of timber so distinctly in the strata of coal, as to be certain that it really had been timber, and that it really was, when I saw it, partly imperfect coal, and partly destroyed or spoiled timber; and it was this observation and discovery that first excited me to inquire and search out the true origin of coal.

Let us now take a cursory view of the coal al-

ready discovered in Britain, in order to give us some idea of the quantity of this very useful mineral. What a vast number of strata of coal is there between Haddington and Edinburgh! between Edinburgh and Stirling! in the shires of Fife and Clackmannan! in the shires of Lanark, Renfrew, Dumfries, and Air, in Scotland! What an immense number in the counties of Cumberland, Northumberland, Durham, Nottingham, Stafford, Salop, and the other coal countries in England and Wales! And yet what is this small island in comparison of the rest of the habitable parts of this globe? But a speck. Nevertheless, it may justly be called a fortunate island. Great Britain is a great word in the mouth of a Briton, yet it is but a spot when we compare it with the rest of the world. What a vast quantity of coal may we then suppose to be deposited in all parts of the superficies of the globe? The quantity must be immense. At the same time, it must be allowed, that all parts of the globe are not so plentifully stored with this fuel as Britain. There is almost none in Britain itself to the north of the Ochil Hills. There is, as yet, but little discovered in Ireland, and still less in proportion in many extensive northern regions. There are extensive tracts of granite and other rocks, not commonly associated with coal, in many parts of the globe, where none is to be expected; but after all these

deductions, the quantity to be found all over the globe must be immense.

It may be properly asked, where I am to find timber enough to produce all this coal? This may at first sight appear to some absurd and impossible: However, it does dot appear to me in that light; and I hope to give a satisfactory account of the matter to every impartial inquirer, before I quit this point of investigation.

I have good reason to believe (contrary to the opinion of many), that there was but a small part of the antediluvian earth inhabited; but as I cannot prove those reasons by indisputable facts, I will not insist upon them, but will leave it as a supposition. It was a small part of Asia, and perhaps a very little of Africa, that I suppose to have been inhabited before the flood; the modern discovery of human bones in the body of the strata, and blended in the composition of the solid rocks in Dalmatia, and in several of the islands in the Mediterranean Sea to the westward of Asia, appears to me to give no small support to that opinion. Let us reflect, that Dalmatia, and the islands in the neighbourhood of that country, are directly in the run of the high tides (upon the supposition of the chaotic state of the earth I insist upon at the deluge), and this at least gives the suggestion a greater air of probability. For we may justly suppose that all such substances would be carried somewhat westward by the high tides

of such a deluge, before they would settle with other matter, and be lodged in strata. Allow me for once to beg the question, where I cannot avowedly lay claim to it by proving the fact; and let us suppose, that only a considerable part of Asia, and perhaps a very small part of Africa, were inhabited before the deluge; and in that case, by far the greatest part of the earth lay waste, and of consequence, all the uninhabited parts of the earth would be entirely covered with the tallest and most luxuriant growth of timber imaginable; and at least one half of the inhabited countries would be in the same condition. America is a sufficient proof that the uninhabited and thinly inhabited parts of the antediluvian earth would be so covered with timber.

Let us examine how much tall timber will grow upon a square mile of good soil, when sheltered by tall timber on all hands: Again, how much will grow upon a thousand square miles, and so on, over the greatest part of the dry land all round the globe; and in this view of the subject, we shall find that the original sources of the coal correspond with the quantity of it in the world.

I will here beg leave to propose another probable source of coal. I believe I may call it a real one, and that is the antediluvian peat-bog. I have really seen strata of coal that have all imaginable marks of being composed of that combustible sub-

stance. The colour, quality, and form in the stratum, the manner of burning, the ashes, and every thing else relating to these coals, look like peat. I have seen dried black peats nearly as hard. These coals exhibit no perfect and regular form and grain in working, like other coals, but break into mis-shapen glebes, like peat-clods broken by water. The roof or upper side of one of these strata of coal is not level or plain like other coals, but very unequal; and a stratum of clay, which is immediately above it, has filled up all the inequalities of the upper side of the coal. There is one of these singular coals at Breich in Linlithgowshire, in Scotland.

Some naturalists have advanced, that peat-bogs are the effects and produce of the stagnations of the universal deluge; and being sometimes found in low situations, with several feet of earth above the moss, and a quantity of large timber trees lying in the bottom of these peat-mosses, they are adduced as infallible proofs of the deluge. For the timber, say they, is antediluvian, and the clay, or sediment found above some mosses or bogs, was certainly lodged there by the waters of the deluge. Some of these mosses are now discovered in maritime situations, and by the sides of great rivers, where the tide flows; and many of them are found lower than the present high water mark, which is reckoned a corroborating proof of the truth of this

hypothesis. Now, as these circumstances seem to coincide and depend upon one another, it may not be improper for me to give a brief account of the natural history of mosses, or peat-bogs, in order to obviate and remove such mistakes about them.

All the peat-bogs upon the face of the globe are certainly post-diluvian. Many of them are of recent formation, and countless numbers are now growing and forming more expeditiously than is generally imagined. Decayed and putrified vegetables are the origin and matter of which all peat-bogs are produced; and decayed and putrified vegetables may, and do increase and accumulate in several situations, and from sundry causes. With respect to such as are found as low, or, as it is said, lower than the present height of the tides, these are most commonly found in flat bays, and by the sides of considerable rivers, and often not far from where these rivers fall into the tide. In some places there is a depth of sediment above these low peat-bogs, and good soil upon the surface, which has been in culture above a thousand years. Some parts of the Carse of Gowrie, and of the Carse of Stirling, in Scotland, may be produced as instances of this kind, where moss is found below, and a good depth of soil above the peat-bog. It is very evident that both of these, as well as many others in the same country, were formerly the bed of the sea. The tide runs up now further than any

part of these two carses; and notwithstanding what many have advanced to the contrary, the tide runs up now every where as far as ever it appears to have run, where the channel is strait and free, and not obstructed and filled up by adventitious matter carried by water and lodged in it. I formerly pointed out the source of the deposition which has filled up bays and formed carses, and other new land, viz. the numberless rivulets and rills washing down the soil off the sides of the mountains and higher grounds; and the superficies of the sandy and argillaceous strata, decomposing and dissolving with the weather, supplies more matter to be washed down from time to time. I showed before, that land floods carry down considerable quantities of this sediment, and lodge it commonly where water stagnates, and especially about the meeting of the salt and fresh water.

The phenomenon of the bog itself being found so very low, is very simple and easily accounted for. A bank of sand, or other matter thrown up by the motion of the water in a storm, would form a pool of stagnated water behind the bank. This pool or lake being shallow, and having a slimy bottom, a rank growth of many vegetables would soon appear; and these vegetables decaying annually, would soon fill up the water, and form a morass, which by degrees would become a peat-bog. Trees might grow so near these bogs, as to be in time surrounded by their increase, which

trees might afterwards be blown down by the winds, and covered by the growth and increase of the bogs, which in many places is much more hasty than is commonly imagined. Or, the trees might be there before any such stagnation of the water happened; and their being blown down might begin a partial stagnation, and produce a luxuriant growth of aquatic plants, which would lay the foundation of the bog. When a depth of peat-bog was produced by these or similar causes, a high tide, and a great land flood, with a storm of wind, meeting and acting with united force, would break over the mound which separated the bog from the waters of the river and tide; and when the barrier interposed between them was demolished, or a breach made in it, the flood would lay a depth of sand or mud above the bog, and future floods would increase it. These bogs being found now as low as the tide, and the tide still flowing further up in such places, are clear proofs that the sea is not retreating from our coasts, as many assert.

The falling of trees, and even the falling of the branches and leaves of trees upon humid ground, may begin a stagnation of water; and whatever begins a stagnation, lays the foundation of a rank growth and putrefaction of vegetables, which is laying the foundation of a future peat-bog. Great numbers of lakes and marshes are now making quick advances to become peat-bogs, by the an-

nual putrefaction of a rank growth of vegetables, and many present peat-bogs were formerly lakes and marshes. There is a beginning of turf or peat-bog in all old fir and pine woods, among the roots of the trees; and where much fir timber is found in the bottom of a peat-bog, there is no room to doubt that the bog was formerly the site of a fir-wood, and that the trees were blown down by violent gusts of wind; and the trees being blown down would increase the stagnation and growth; and of course, the fallen trees would be soon covered with peat-bog *.

There is now an annual increase of such bogs, by the decay of various kinds of vegetables, where they are neither washed away by streams of water, nor blown away by the winds; but of all the feeders of peat-bog, the most common and the most plenteous is heath, and heath is found plentifully in all cold countries, and especially upon poor, sandy, gravelly, and boggy soils. I have seen many peat-bogs with heath growing upon

* This history of the progressive formation of moss corresponds exactly with the account given by the Earl of Cromarty of what fell under his own observation, and perhaps refers to it. See Phil. Trans. XXVII. 296. For farther information on this subject, the reader may consult, with great advantage, a very interesting work, entitled, Essays on the Natural History and Origin of Peat-Moss, by the Rev. Mr Rennie of Kilsyth. —EDITOR.

them, the surface of which consisted of a foot and a half, or more, of the branches, blossoms, and seeds of the heath, apparently not in the least decayed. The second stratum down consisted of the same matter beginning to decay a little. The third course produced bad, light, imperfect peat, called *flow moss* in Scotland. The fourth, and so on, still better and better peat, the farther down, until it became, at a sufficient depth, perfectly black, and of a close texture, being well digested peat-bog. This is a sufficient description of Moss-Flanders above Stirling, of the moss of Kintraw in Ardnamurchan, of the Solway moss, and of almost all the mosses in the Highlands of Scotland.

But to leave this digression: The other coal metals, or the strata which accompany coal, are as clear a proof of the universal deluge as the coal itself, or nearly so. Many of these have a small quantity of the coal between their folds and laminæ, and in small nests within the solid parts of the strata; and these concomitants of the coal are all as regularly stratified as any other class or assemblage of strata whatsoever. There is one among these besides the coal, which deserves particular notice, and that is the iron-stone. The iron-stones of the coal-fields are disposed in regular strata, and there are in some coal-fields a great number of strata of iron-stone. These strata of iron-stone are generally thin; the medium thickness is from two to five or six inches; but they are neverthe-

less as regular strata as the coals themselves, and spread as far every way as any of their concomitant strata.

Now, every intelligent unprejudiced naturalist, who has taken any notice of the order and disposition of the several strata in a coal-field, must acknowledge, that those several strata were spread out and formed, in the order we find them, by successive tides, or by similar streams of water, bringing the matter and depositing it in regular strata. The order in which they are placed, *stratum super stratum*, promiscuously, in respect to the laws of gravitation; the heavy, the light, and those of medium weight, being all blended together, without the least regard to gravitation, make it evident that they were deposited in the order we find them by successive streams of water. Any other way of accounting for this deposition, will not agree with the phenomena of nature. The bands of iron-stone in the coal-fields are commonly found in the black and grey argillaceous strata called *till* or *blaes*, which generally accompany coal; and we frequently find two or three, or more, thin strata of iron-stone in one thick stratum of blaes. But it should be observed, that all the iron-stone of the coal-fields is not stratified, or found regular and continuous in the manner of any regular strata. We often find and work iron-stone in nodules, balls, and glebes, which are deposited promiscuously without any regular order.

This ball iron-stone is always of the same quality as the regular strata of iron-stone found in the same coal-fields; and the balls and glebes always appear water-rounded, being either found in smooth roundish balls of various sizes, or else in flattish glebes with obtuse angles or smooth rounded edges. Now, the situation, order, and figure of this ball iron-stone, are another proof of successive tides in the formation of the strata. This glebous iron-stone was first of all formed in regular strata of various degrees of thickness; but before induration was completed, a stream tide, accompanied by a strong wind, has ploughed up and torn off part of the superficies of the strata of iron-stone and others already formed; the fragments of which strata, when torn off, were easily rounded by rolling and attrition in the water, before they were perfectly indurated; and these fragments were afterwards deposited by succeeding tides in the soft argillaceous strata already mentioned; which strata of coal tills, holding glebes of iron-stone, and such other strata as are found above them, must have been formed later than the regular strata of iron-stone from whence these glebes were torn off. That they were torn off from the superficies of regular strata, is evident, from the glebes and balls being of the same colour, quality, and texture as the strata.

The richest and purest iron-stone of the coal-fields is generally of a fine texture, commonly ri-

sing in small angular masses from the stratum, fragile, and easily broken into small angular masses of different figures; and we find the purest and richest ball-iron in exceeding small masses, imbedded in the strata of coal-till, of various colours. On the contrary, strata of inferior quality have a coarse grain and texture, are more strong and cohesive, and rise in larger glebes in working it from the stratum. Some of the inferior kinds, when the strata of iron-stone are not above three or four inches thick, rise in broad flat cakes or glebes; and I have frequently seen them in as broad and flat masses lodged in the coal-tills, with only the edges or sharp angles a little worn off. Such glebes of iron-stone as have been broken off from thinner and thicker strata, still retain evident marks and characters of their stratified state, as the various masses and fragments clearly discover the bed of the stone, having only the asperities and sharp angles worn off. I have endeavoured to explain this phenomenon with some degree of perspicuity and precision; because I think it deserves attention, being a clear and convincing proof of the formation of the strata by successive tides.

I observed before, that the various strata found in coal-fields, are as finely stratified, as regularly spread out, and as equally thick in continuation, as any class or assemblage of strata whatever; and I will now observe, that the coal itself is likewise

as fairly stratified, and as regular, as any of its concomitant strata. Many beds of coal are so finely stratified, that they really are of a laminated structure, the plates or different laminæ being thin, and splitting regularly in leaves of equal thickness, the whole breadth of the largest masses. Now, this is a clear proof of the agency of water in a gently flowing motion. If these northern regions were not inhabited, they would soon be overgrown with wood, and especially with pines, or fir-wood. Tar is extracted from fir-wood; and it is remarkable, that of late years it has been discovered that a species of tar can be extracted from coal, which is procured in great abundance by a sort of distillation. I cannot help thinking that this known fact is a good collateral proof of the antediluvian timber being the origin of coal. This mineral tar has a fetid, disagreeable smell, which, no doubt, is caused by its being combined with vitriolic and other heterogeneous particles. The coal from which this tar is extracted being in a mineralized state, and mixed with various other matters, we cannot expect it to be as simple and pure as the resins of timber, but they are really of the same quality.

Let us suppose that all the particles of matter of which coal is composed are really existing; and let us suppose them to be thrown, or any how carried into the ocean, according to the wish of the modern philosophy; if these particles be left

to chance, when blended with the particles of an infinitely greater quantity of matter entirely of a different quality (which matter we find disposed in different strata along with the coal), the known laws of gravitation would render all these combustible particles entirely useless to us. According to those laws, the stony and metallic particles would either be found mixed and compounded with the coal; or rather, they would all sink down under it, in the order of their specific gravities. In either case we should have no coal.

I think that I made it sufficiently evident, that neither coal, nor any other regular strata, could possibly be formed by subsidence in water, that is, by the particles of matter subsiding to the bottom of the ocean, without a miracle. That I may illustrate this matter farther, I will observe, that we have occasion to see many natural and artificial operations, which clearly evince the truth of what I assert. We know by experience, that when grains or particles of different degrees of gravity are agitated in water, the more ponderous always sink down below the lighter. I will give a complete instance of this in an artificial operation. The slime-ore, or smaller grains which the water inevitably carries away with it in dressing the ores of tin and lead, &c. is saved in small ponds, or holes dug in the earth, in which the water that runs from the washing operation stagnates, and the slime carried with the water falls to the bot-

tom. When these slime-pits are full, the stream of water is turned off, and the sludge is thrown out to dry. The mineral washers have many nice and curious methods of dressing this sediment, in order to separate the heterogeneous particles from the metallic.

We cannot expect the same nice exactness in chance work: however, particles of matter, mixed and agitated in the waters of the ocean, and afterwards subsiding to the bottom, comes as near their operations as any thing that can be imagined in nature or art; of consequence, coal, and other distinct strata, could not be formed by subsidence in the waters of the ocean without a miracle; and I am not willing to admit or allow miracles to be introduced, where the operations of nature, and the agency of second causes, will do as well. I observed already, when viewing the coal metals, that the laws of gravitation were not consulted or admitted in the formation of those strata; and therefore it is necessary for us to acknowledge that they were formed by the flowing of successive tides.

I have already made it pretty evident, that the greatest part of the surface of the earth, before the deluge, was covered with a luxuriant growth of tall timber, that this, antediluvian timber is the origin of our pit-coals; and that it was a sufficient and an adequate source of all the coals in the world. I am of opinion that the antediluvian

timber floated upon the chaos, or waters of the deluge, until the strata of the highest mountains were formed, with much of the other strata in our sight; and that during the height of the deluge, and the time in which the greatest part of the strata were forming, the timber was preparing and fitted for being deposited in strata of coal; and that the coals, with their concomitant strata, were among the last that were formed. But how, and by what means, every thing in this great work was fitted and carried on, belongs to higher wisdom and intelligence than mine to explain. However, we may examine what we can see with our eyes, and what is to be seen we may investigate by the aids of philosophy; and it is allowable for us to draw such inferences as naturally and inevitably result from our observations and discoveries.

Wheresoever I have seen the strata of the coal metals terminate, and the strata of the mountain rocks succeed, whether in the longitudinal line of bearing, or across the strata, the coal metals always ride uppermost; are troubled, confused, and good for nothing, and commonly dwindled away to little in thickness; whereas, on the contrary, the strata of the mountain rocks emerge from under the disturbed coal metals in full perfection of quality, strata, and bearing, &c.; and therefore I am obliged to conclude that the strata of coal, and

their concomitants, were among the last which were formed.

I have frequently stood upon the summit of a high mountain in a clear day, and taken a general view of the outlines of this great subject; and from such elevated situations, and indeed every where else, I see deep and evident marks of the amazing effects of the high diluvian tides, even after the higher mountains and other elevated parts of the earth were formed. All the long and deep channels through chains of lofty mountains, were cut out by the running of these weighty tides; all the gulfs and deep bays upon the face of the globe, were scooped out by the prodigious weight and force of the violent agitation and progress of the tides of the ocean from east to west.

A philosopher, who is much out of doors, and traverses mountainous countries, who admires these grand and magnificent scenes of nature, intent upon discoveries of truth, and who is not wedded, or rather enslaved to system, cannot fail of seeing the evident marks of these tides we are speaking of upon the whole varied face of the earth. The Mediterranean, the Red Sea, and all the other inland narrow seas, were cut out and produced by the violent progressive motion of those high and weighty tides. It was the weight and force of these prodigious tides, even after the mountains and elevated plains were formed, that

have cut out all our sounds and deep channels between the continents and islands; that have cut through the islands, and disseminated them over the face of the deep.

The weight and force of tides, which perhaps were several miles of perpendicular depth, have made mighty efforts to wash away the whole face of the dry and solid land, and mix it again with the waters into a chaos.

The weight and force of these tides were so very great, that they have nearly cut a passage through the middle of both continents. In their progress from east to west, they have ploughed up the channels of the Red Sea and the Mediterranean, which was a mighty effort to dissever the old continent, and gain a clear passage to run quite through. This passage was nearly completed; nothing but the narrow isthmus of Suez remaining to connect Asia with Africa. Similar effects of these tides are as evident in the new continent as in the old. The gulf of Mexico upon the one side, and the bay of Panama upon the other, are sufficient instances to support this assertion, where nothing but the isthmus of Darien remains to connect North and South America into one continent.

It was hinted before, that the gulfs were scooped out, the islands dissevered from the continents, and from one another, and the sounds and channels were ploughed up by the weight and force of

the high tides, after the highest mountains, and other elevated parts of the globe were formed; and even after the tides were fallen so much as not to flow over the most lofty mountains and elevated plains. In the height of the chaotic state of the terraqueous globe in the universal deluge, the tides flowed clear over every thing from east to west, without obstruction; and even after numbers of the highest mountains were formed, the tides were still high enough to flow clear over the main parts of both continents, though not over the summits of the highest mountains: But when more elevated lands were formed, and the stratification of the superficies of the solid parts of the earth was pretty far advanced, the tides would then fall gradually and proportionally lower.

It has been shown, that the high tides, after the land began to be formed, purged the ocean of the earthy matter, and every succeeding tide laid more solid matter on the face of the ground; which was spread out in regular strata by the stream or flowing motion of the tides which brought it there. All chains of mountains, it was also observed, were at first elevated plains, and the high tides flowing over them cut and dissevered their summits, and excavated and formed their deep valleys.

The marks of forcible runs of water are evident in all the irregularities of the mountains. But all

these primitive elevated plains were not cut through in a thousand places like our mountains, or disfigured, but remain to this day; such, for instance, are the elevated plains of Abyssinia, some of the south-eastern parts of Tartary or Buckaria, and the elevated plains of New Grenada in America, all of which are countries of great extent, and raised higher above the level of the sea than our European mountains. If all the mountains were elevated plains at first, and if the elevated plains now mentioned are as high above the level of the sea as our mountains, how comes it to pass that these remaining high plains were not cut through and dissevered by horrid gulfs and valleys, like our rugged mishapen mountains? I answer briefly, the tides fell so low, by discharging and lodging much earthy matter upon the land, immediately after the formation of those elevated plains, that the water could not flow often enough over them to cut them asunder and disfigure them. But when all the highest mountains and the elevated plains appeared at all times above water, and were no longer overflowed, not even by stream tides, it was then, when much dry land ceased to be overflowed by the tides, that the still comparatively high and forcible tides made such powerful efforts to cut through the continents and islands in all parts of the world. It is well known, that the tides rise high and run with great force in the torrid zone. The high chaotic tides would run

with proportionally still greater force there than at present; and it is in the torrid zone that the greatest marks are found of their effects. On the east and south-east sides of the continents, they have left deep and indelible traces of their powerful efforts: They have pushed far into the main land, in the gulfs of Siam and Bengal, and still farther in the gulf of Persia; but they were every where repelled by high lands, until they came to Babelmandel, and there they entered the Red Sea, passed over the low lands of Egypt into the Mediterranean, and so quite through the Old Continent into the Atlantic ocean. The high tides continued to flow through the middle of the continent until they fell nearly as low as at present; and then this passage was shut up and barred against the common tides by the isthmus of Suez, and the main ocean was obliged to flow south by the Cape of Good Hope, before it could come into the Atlantic.

While the diluvian tides continued so high as to pass over the land of Egypt into the Mediterranean, the run of the Mediterranean westward, joining the tide of the main ocean upon its entering the Atlantic, would make a very strong and powerful tide in the gulf of Mexico, and the effects correspond with our idea of the weight and force of these tides. The numerous and extensive range of the West India islands, and the gulfs of Maracaybo, Darien, Honduras, Nicaraqua, and

others, are sufficient proofs of the force of the Atlantic tides, and of their efforts to cut a passage through the middle of the New Continent. The later high tides passed over the isthmus of Darien in the New Continent, as well as over the isthmus of Suez in the Old; and similar circumstances may be observed in both these passages. The New Continent is divided into two great parts by the isthmus of Darien, in the same manner as the Old Continent is divided in two by the isthmus of Suez. The isthmus of Suez and of Darien, though in two different continents, and removed to such a vast longitudinal distance from one another, are nearly in the same parallel of latitude, which is about ten degrees north of the equator. It is evident, that when the land was mostly formed, and the tides were fallen considerably lower, though strong and violent, yet in this state they could not make way over the elevated plains of New Grenada, and the lofty and extensive range of the Cordilleras and Andes, to the south of Darien, or over the immense and elevated countries of Mexico, and other parts of America to the north of Darien; and therefore the isthmus of Darien, or Panama, was the only passage which the later high tides could find for the ocean to pass through the middle of the New Continent, as it had passed through the middle of the Old: but when the sea was thoroughly purged by the tides of earthy matter, and the dry land was all formed, the tides

then fell so low by degrees that they could not pass over Darien.

From the examination of these facts and circumstances, it is evident, and deserves to be remarked, that the middle of both continents was at first formed lower than both ends; that is, from the island of Socotora upon the east, to the bay of Cadiz upon the west of the Old Continent, was all low land, much lower than the extensive lands to the north and south of this low tract, over which the diluvian tides passed for some time after they were fallen too low to pass over the whole extent of the Old Continent; and in this Mediterranean passage the tides ploughed a deep channel all the way through from east to west, excepting the narrow isthmus of Suez. The middle of the New Continent was also at first formed low land, as well as the Old, and very nearly in the same parallel of latitude. The first low plains in the middle of the New Continent seem to have reached from the island of Porto Rico to the bay of Panama, over which the strong confined tides made way, and cut a passage quite through the middle of the New Continent, excepting the narrow isthmus of Darien. It may be difficult to give a satisfactory reason, why the middle of both continents should at first be formed much lower lands than the two ends; however, I will offer what occurs to me in explanation of this singular fact.

It is allowed by all, that the torrid zone, or the

equator, is the highest part of our globe ; of course, the zone or girdle of the equator is longer than any other zone of the earth. This greater length of the zone gives the equatorial tides a greater length of space to pass over in every revolution, than in the other divisions of the globe; and moreover, the torrid zone being under the perpendicular rays of the sun, the powers of attraction are greater there than in any other division of the globe.

When the land and water were blended together in the chaotic state of the deluge, the powers of attraction would raise the chaotic tides proportionally higher in the torrid zone than in any other parts of the globe. The Cordilleras, and other high mountains, and the elevated plains of New Grenada and Abyssinia, &c. make it evident that the tides were exceeding high in the equatorial regions. These high tides, having such a vast zone to encompass in equal spaces of time with the revolutions of the tides, without the tropics, where the zones are much shorter, it is evident that the equinoctial tides must run with a stronger and swifter current than at the tropics, and much quicker than in the temperate and frozen zones of the globe. This is necessary from the nature of things. The revolutions of the tides being performed in the same length of time in all parts of the globe, the equatorial tides, which had by much the longest course, must of necessity run quick-

est, to pass over a greater space in the same time. Let us suppose that the diluvian tides at the equinoctial line would rush forward in a bold current, like a river in flood, and then we shall be able to comprehend the reason, why the land is lower near the equator than in the rest of the torrid zone upon both sides. The tides in this track would always run with a current too strong, eighty, and swift, to allow mountains of granite and others to subside, or regular strata to be formed to any considerable height. But this mighty run of the main current at the equator would produce eddies at some distance upon both sides, where mountains of granite might subside; and strata might be formed by a more temperate and leisurely current and motion of the tides.

I observed already, that the chaotic tides rushed forward from east to west in two great streams in the twenty-four hours; that the time of rest between each tide is high water, and the places of rest the two great continents: I mean, during the height of the deluge, or chaotic state of the terraqueous globe. Upon this supposition, the tides in the intervals of each gush, at high water, would rest a little upon each continent, or at least they would not rush forward so precipitately for some space of time at the turn of the tide. This small and partial interval of rest, or of slower motion during the height of each tide, would be more considerable at some distance from the equator

upon both sides, than immediately under the line, which intervals of time would not be lost. The formation of the solid land would advance rapidly in these times and places; but under the equator, the tides would not have much time to rest, the intervals would be less considerable than upon both sides; and therefore the superficies of the globe was not formed so high in this great run of the tides over the Old and New Continents, as at some distance upon both sides.

I suppose tha. the long chain of isles reaching from the island of Trinidad, upon the south-east, to the Straits of Bahama, upon the north-west, was formed at first in one continued plain or regular connected piece of land of no great height, but containing however some considerable mountains, which still remain in St Domingo, Cuba, Jamaica, and in some other islands; but that the high tides of the Atlantic Ocean cut through, and separated them from the Western Continent, and from one another. When so much of our dry land was formed, that the tides did not rise so high as to pass freely over the ends of both continents, but still continued to run through the middle of them, a strong and powerful tide would then pour into the Atlantic from the great South Sea, between the Cape of Good Hope and Cape Horn; and when this great tide was joined by the powerful current which rushed through the middle of the Old Continent, the united force of both

would have powerful effects upon the lower parts of the New Continent. It was then that the long stretch of land, reaching from the river Oroonoko to Florida, was ploughed up and torn to pieces by the mighty efforts of those tides, to make a free passage through the middle of the New Continent, which was very nearly effected, nothing being left between the two seas but the narrow isthmus of Darien.

The tides which came between the two continents into the Atlantic, have cut deep into the land in many of the northern parts of Europe and America. Their effects are very evident in the many seas, bays, and gulfs, which are scooped out of the bosom of the northern parts of both continents; but it does not appear that they found, or that they made, a passage quite through the dry land in the northern parts of the earth. These tides might find low lands in the north, over which they might flow for a long time, as they passed over the isthmus of Suez and of Darien; but I am persuaded that all the passages of the tides in the north are now barred up, as well as the passages farther south.

I have seen the narrow isthmus at the north end of Cantire, which joins that peninsula to the main land of Scotland; and I have seen many other low and narrow bars between two seas or bays, over which the high tides I am speaking of passed freely; and I have every where observed, that

these low and narrow necks of land consist of exceeding hard rock, which the most weighty and forcible tides could have no effect upon to wear down; and this is the cause which prevented the peninsula of Cantire, as well as many others, from being islands. This isthmus or rock which joins Cantire to the main land, is not above a mile over at high water in stream tides; and I believe that the highest part of the rocky bar is not thirty feet above flood-mark.

Voyagers inform us, that the isthmus of Darien in America is rocky ground; and I am certain it must be so, and that those rocks are very hard and strong; otherwise the forcible tides which rushed from the Atlantic, over that isthmus, would have cut through and torn away this bar, and made a deep and wide channel between the gulf of Mexico and the bay of Panama. I know nothing about the natural history of the isthmus of Suez; but we are well informed that Egypt abounds in excellent granite quarries; and therefore, whatever may now appear at the surface of the ground in a country over-blown with sand, it is probable that there may be a bed of hard granite below the sand or soil of the isthmus of Suez.

The highest mountains of the globe generally consist of granite rocks. These were formed during the highest state of the chaotic tides. The highest mountains are found within the tropics or under them, but not immediately in the run or

current of the tides near the equator; which suggests to us, that the main current of those tides was too strong, rapid, and constant, for the subsidence of such quantities of matter in a short space of time, as is required to the formation of ranges of high mountains. We observed before, that all the ranges of mountains between the tropics trend from north to south, but the line of the mountains without the tropics, upon both sides of the equator, falls a little back to the eastward; so that in Britain, and in parallel northern latitudes, the longest ranges of mountains trend from about S. S. W. to N. N. E. and they fall back to the east proportionally in equal southern latitudes.

The elevated plains of Abyssinia, and the Mountains of the Moon, in the interior parts of Africa, stretch in a continued range with little interruption all the way south to the Cape of Good Hope. This great range trends due south, from about the fifteenth degree of north latitude to Monomotapa, when it inclines a little to the east, until it reaches the neighbourhood of the Cape, in about the thirtieth degree of south latitude.

The northern great range of mountains of the Old Continent, commences somewhere about the latitude ten or fifteen north, and it stretches away due north through the Mogul Empire, and through Buckaria, until it joins the elevated plains of Independent Tartary, where it begins to lean a little

towards the north-east; but in general, it stretches northward, with little interruption, until it terminates in the extremity of the north. This is a longer and more extensive range than that which trends away south through Africa. The great range of the Asiatic mountains is not only of immense length from south to north, but it is also of great breadth from east to west, though with considerable interruptions, which in fact divides them into several ranges. The European great range of the Alpine mountains stretches away north from Monaco, upon the east side of the gulf of Genoa, through Savoy, Switzerland, and Germany, and, with some little interruption, continues a northern, and somewhat eastern course, to the extremity of Lapland. The principal range of mountains in the island of Britain, keeps the same general course from north to south, with a lean towards the north-east. This range commences in Caithness, in the northern latitude of fifty-eight, and it stretches southward through the countries of Sutherland, Ross, Inverness, and Argyle, seemingly terminating in the island of Arran. The eastern division of this great range of British mountains commences in Banff or Aberdeenshire, stretches southward through the counties of Aberdeen, Angus, Perth, Stirling, Dunbarton, Renfrew, Air, Galloway, Cumberland, Westmoreland, Lancaster, Flint, Denbigh, Merioneth, Montgomery, Cardigan, and terminates in Pem-

brokeshire in South Wales. The interruptions in this range are not great.

The American ranges of mountains likewise trend from south to north. The highest mountains upon the face of the globe are those of South America, and among these the Cordilleras are distinguishable, for their vast height, magnitude, and extent. The principal range of the mountains of South America commences in the mountains of St Martha, in about the tenth degree of north latitude, joins the elevated plains of New Grenada, and stretches away due south in a lofty magnificent ridge, parallel to the west coast, all the way to Patagonia, and with very little interruption to Cape Horn, in about fifty-five degrees of south latitude. This is a very long and regular range of mountains.

The mountains of North America, though more extensive, are not so regular and lofty as those of the south; and therefore the ranges cannot be so distinctly traced out. The Apallachian mountains, which commence about the thirtieth degree of north latitude, trend away northward through Canada and Labrador, and perhaps through Greenland, with the interruptions of Hudson's and Davis's Straits. This is a considerable range of mountains; but I suppose that the most extensive range in North America, stretches along the west side of the continent, not far from the west coast, from about the twentieth degree of latitude to the extre-

mities of the north, and north-east, where America joins the continent of Asia, an extent of more than four thousand miles.

Many philosophers and naturalists assert, as an established fact, that all ranges of mountains run from east to west; but this assertion is founded upon very limited and imperfect views of the subject. I grant that, from a cursory and partial view of the mountains of all countries, they do appear at first sight as if ranged from east to west; but this is too hasty a conclusion. The running of the high tides from east to west, over the ranges of mountains, have scooped out valleys in that direction; and by that means dissevered the mountains from one another, into ridges of different lengths, running from east to west; but these are only the effects of the tides, running at first over those high lands, when they were elevated plains; the prodigious weight and force of which washed away the earthy matter out of the excavations, and left them as we find them in the form of mountains: But that the mountains in general really are ranged from north to south has been clearly proved.

Before I dismiss these speculations upon the outlines of the superficies of our globe, I will beg leave to remark, that I perceive some phenomena and some facts which I cannot account for.

Most of the dry land of our globe is situated to

the north, and the lowest parts through the middle of each continent, at the isthmus of Suez and of Darien, which appear to have been the principal currents of the high equatorial tides, are considerably to the north of the equator; but I cannot perceive the natural cause of this. It is acknowledged by all intelligent men, that the Old Continent is more extensive than the New. Some say it is more than twice the extent; however, the late discoveries of Captain Cook, upon the west coast of America, make it evident, that the northern parts of the New Continent are much larger than was formerly supposed. But what may really be the different comparative extent of each continent, I cannot determine. It appears, however, that of the Old Continent, all Asia and Europe, and more than one half of Africa, are situated upon the north side of the equator; and of what properly belongs by situation to the old part of the known world, nothing but the lesser half of Africa, with New Holland, and some lesser islands, has been yet discovered to the south of the equinoctial line; and I am persuaded that there is not much more to be discovered. Matters are not much different in America, with respect to the disposition and situation of the dry land. America is considerably longer from north to south than the Old Continent.

The south end of Patagonia, which is the southern extremity of the continent of America, is laid

down by geographers about twenty-five degrees farther south than the Cape of Good Hope, which is the south point of Africa, and the great island of Terra del Fuego is still farther south than Patagonia. But although America is much longer from north to south than the Old Continent, it falls very much short of the breadth of the Old from east to west. But whatever may be the different proportions of the extent of the surface of both continents, it appears that there is more of the New Continent situated to the south of the line than there is of the Old. But although there is such a small proportion of dry land in the southern hemisphere, the highest mountains in the world are found upon the south side of the line. The elevated plains in the middle of Africa are of great height. The Mountains of the Moon and of Monomotapa, to the south of the line, are erected upon these high countries, which must raise them a prodigious height above the level of the sea.

This chain of mountains is of great extent from north to south, stretching from the line into the southern parts of Caffraria; and it is highly probable that the end of this chain, which is situated next the equator, is the highest of any mountains in the Old Continent.

It is well known to naturalists, that fluid bodies, especially water, are attracted and put in motion by the influences of the sun and moon; which undoubtedly is the cause of the tides of the ocean.

This being well known, it must of consequence be granted, that the greater the extent and depth of water exposed to the heavenly influences, the greater will be their effects, and the higher the tides will be raised.

From this consideration, we are led to conjecture, that in the height of the chaotic state of the deluge, there was less earthy matter mixed in the ocean to the south than to the north of the equator; and consequently, the tides would be raised highest upon the south side, which is the cause of the highest mountains being found in the southern hemisphere. But why there should be more earthy matter upon the north than upon the south of the line, we have no foundation so much as for a conjecture.

I WILL now offer a few observations concerning the mutations of our globe. In the last general heads, I pointed out and explained several clear and incontestible proofs of an universal deluge. The observations I mean to advance at present, derive their force and importance in a great measure from their connection with, and relation to my former observations, in proof and illustration of the doctrine of the deluge.

My remarks upon the fragments of quartz, schorl, and mica, &c. will in time appear, to the candid and intelligent, to be decisive proofs that they are fragments of some original strata, which

strata we can no where find; nor can we give any account or rational conjecture about them, without allowing of what was universally believed by all antiquity, and celebrated by many of the most ancient poets and philosophers of different nations; I mean the primeval state of the earth before the deluge.

I reckon it a certain fact, that the quartz, schorl, and mica, with all the fine grains found in the composition, and in the decomposition of our rocks and strata, which are not of a prismatical figure, are fragments and remains of the antediluvian strata; and I think it probable, that all our metallic and mineral ores were disposed in strata in the antediluvian state of the earth. I think it probable, that the metals were all originally in a pure and malleable state; and that the strata of original metals, as well as all others, were broken to pieces, and mixed with the waters in the chaotic state of the terraqueous globe; and that by the motions of the tides, they were all ground down to small grains and particles, which were afterwards mineralized, or mingled with heterogeneous mineral matter, before these compounds were deposited in our mineral veins, and in the composition of some of our strata *.

* These are certainly very bold conjectures, some of which will probably meet with few supporters; particularly with regard to the component parts of granite, to which the Author

A great deal might be said about the origin of the antediluvian strata; but as it must all be hypothetical, I will not dive into such uncertain and useless conjectures. But notwithstanding this resolution, I would not have it understood that I give up the point as uncertain. I have made it abundantly evident, that such strata certainly did exist. I hinted before, that the various fine grains and fragments, which are found in the composition of our strata, have all the appearance and characters of originality.

We can divide the plates or laminæ of talc into an inconceivable degree of fineness. What sort of particles then must such bodies be composed of? and the other grains seem to be equally fine. If we should decompose any of these bodies, and look for the original particles which compose and make up the mass, I suppose we should not be able to discover them. We should find them evanescent; but our strata are not so. If any of our strata are decomposed, we can discover and give an account of the component parts, which are quartz, schorl, mica, and various other fine pure grains; but if we look for the atoms which make up these fine grains, we shall find them evanescent in our hands.

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seems to allude, being fragments of the antediluvian strata, and the metals being originally disposed in strata and in a state of purity.—EDITOR.

The inconceivable fineness, and homogeneous purity of the whole mass of these original fragments, suggests to me one remark, which I beg leave to offer, viz. As there are no perceptible grains or particles in these fine fragments, it is evident to me, and will appear evident to every candid inquirer into these matters, that our globe has suffered only one great change by water, or otherwise. These original fragments do not point out to us any thing whatsoever that might suggest the idea of several deluges, or of the earth having suffered several great mutations by any means whatever. The component parts of our rocks and strata clearly point out to us the necessity of acknowledging that our globe has suffered one great change by water; but the phenomena of Nature go no further. We are obliged to acknowledge, whether we are willing or not, that this one change was accomplished by the agency of water; for it is now very generally known, that the marks of water are conspicuous all over the superficies of the globe. The fineness and purity of the essence and quality of these original fragments, not only suggest to us, that the earth has suffered but one change, but they also point out to us an ocular demonstration of a revealed truth, viz. that the Almighty in the beginning created all things out of nothing. Moses speaks of "all things which the Lord God created and made." When Moses says, that the Lord God created the heavens and the

earth, and all the hosts of them, the word *create* seems to me to point at the act of the Almighty will and power in the first production of matter; and the word *made* seems to point at the proper use of matter in the formation of worlds, animals, vegetables. But these are depths not to be sounded by me, and therefore I will only touch them lightly; however, I cannot help thinking that the fineness and homogeneity of the original particles of matter justifies my saying so much.

That a considerable quantity of mineral and metallic ore is blended in the composition of some of our strata, is evident.

Iron is commonly found in the composition of a great number of rocks. I have seen lead blended in the composition of the strata in many places. The tin grains in Cornwall, found in the composition of a species of granite, is another instance.

If there was no more pure virgin metal found in the world, my supposition of the ancient state of the metals would be more doubtful; but there is a good deal found in that state in many parts of the world; and it is worthy of attention, that the quantity of pure virgin metal found in a malleable state, is in exact proportion to its toughness and ductility.

1. Gold is found in small masses, and in grains of various sizes, but always in its virgin malleable state, blended in the composition of the rocks, and

mingled in the sands of rivers and rivulets, from the decomposition of those rocks.

2. There is more silver found in a pure and malleable state than of any other metal, excepting gold. I suppose that the tough and ductile property of gold is the natural reason of its not being broken smaller by the attrition of the fragments of rocks in the agitation of the chaotic state of the deluge; and it is remarkable, that silver is next to gold for toughness and ductility; and accordingly the proportion of each found in a pure virgin state corresponds exactly with these properties.

3. Copper is more tough and ductile than lead, and less so than silver; and accordingly we find more pure malleable copper than of lead, and less than of silver.

Whether the learned naturalist will agree with me concerning the ancient state of the metals or not, he must acknowledge, that this series and gradation which I have pointed out countenances my opinion. There must be some reason for this gradation; and I think he cannot point out one that corresponds so well with the phenomena of the composition of the strata. I suppose that this hint is new, as well as many others in these papers; and therefore, no doubt but they will startle such naturalists at first, as have not been accustomed to view these subjects in the same light with me: however, I hope it will be acknow-

ledged that my observations are founded in Nature; and I declare that it was not the affectation of novelty, but the love of truth, that prompted me to communicate them to the public.

Naturalists have been greatly puzzled to find a quantity of water sufficient to cover all the earth, to the depth of about forty feet above the summits of the highest mountains, so as to produce an universal deluge, as described by Moses. But if we suppose that the original strata of the antediluvian earth were somehow or other dislocated, broken to pieces, and mixed with the waters of the ocean in a chaotic state, then the difficulty is removed, by removing the mountains, and mixing them in a chaos with the waters. In this view of the subject, there were no mountains to be covered, until they were afterwards formed by the high tides of the deluge. All the visible fine grains found in the composition of our present strata, are clear indications of the former existence of such original strata as I speak of. At the same time, it does not appear to me an easy matter to explain how those original strata were broken down and mixed with the waters. The inspired historian Moses acquaints us, that there was no rain in the antediluvian earth, but that the face of the ground was watered by mists instead of rain, which is not improbable. There are some countries which never rain in the present state of things; such, for instance, as Egypt in the Old Continent, and Peru

in America; but we frequently see thick mists in these countries. Upon the supposition of there being no rain in the antediluvian earth, the strata which composed the superficies of that earth would want moisture, and of consequence they would become full of cracks and chaps by drying too much; the dry external air would be admitted into their cracks and fissures, which would waste the cohesion of the rocks, and hasten their decay near the surface.

The rains descending seasonably upon our mountains and plains, entering the superficies of the strata, and passing through their interstices, keeps them continually fresh, and preserves the cementing quality in perfection: But if the antediluvian strata wanted the moisture communicated by rain and melted snow, undoubtedly they would crack and moulder, and approach rapidly to decay; and if, at any future time, water or excessive rain were to overflow suddenly upon the strata thus cracked and over-dried, it would separate and burst the strata into small fragments and masses of various sizes.

Mr Whiston the astronomer affirms, that a comet passed by the earth at the very time when the universal deluge happened; that the earth passed quite through the atmosphere and tail of that comet; and in consequence of this near approach of the comet, that the earth acquired a great quanti-

ty of watery vapour, which fell down in heavy rain upon the earth. This is not contradicted by other astronomers. If this comet approached so near the earth, besides the watery vapour which the earth would attract from it, the comet would certainly have a mighty effect in disturbing our atmosphere, in causing excessive rains to descend from thence, and in raising the tides of the ocean to a monstrous height; which tides would overflow the land, and by their prodigious weight and force would tear up the antediluvian strata, and soon break them to pieces, when mixed with the water; and the strata thus dislocated and broken up, either by the descent of heavy rains, or by the tides overflowing the parched land, their destruction would advance rapidly, until the solid surface of the globe was broken to pieces, and blended with the waters.

I exclude from my observations all concern with central waters issuing out of the bowels of the earth, to overflow and disturb the surface. I do not know that any such waters exist. I have no doubt but this planet of ours has some relation and connection with all the other planets of the same system; but what degree of density and gravity, &c. in proportion to its magnitude and situation, is requisite to answer its relation to the rest, is out of my power to know; and without this knowledge, there is no ground left for me, so

much as to form a probable conjecture, whether the centre of the earth be solid or fluid *.

Some philosophers oppose the doctrine of an universal deluge, from the supposition of its absurdity; alleging that it reflects dishonour upon a wise and intelligent Creator, to suppose that he would make any of his works so imperfect as to require an after-change or reformation. But we find Nature full of change. These changes are most striking in animated Nature, where the transformations may be properly called advances to a better state. The sordid caterpillar of last season is now a shining butterfly, floating at pleasure in the ambient air, and sipping the nectar of every flower; and we hope for a greater change: In short, Nature is full of change or advance; but

* The density of the earth has been determined by Dr Hutton of Woolwich, from the observations of Dr Maskelyne on the attraction of the mountain Schehallien in Perthshire in the years 1774, 1775, and 1776. This attraction, and the mass of the mountain, which was computed from sections in all directions, being compared with the known attraction and magnitude of the earth, gave by proportion its mean density, which is to that of water as 9 to 2, and to common stone as 9 to 5; so that the absolute gravity, or mean density of the whole mass of the earth, is $4\frac{1}{2}$ times greater than the density of water, and nearly double the density of common stone; and from this it is conjectured, that the internal parts are occupied by considerable portions of metallic substances. Phil. Trans. LXVIII. 785.—EDITOR.

why it should be so, why all creatures are not made perfect and permanent at first, is too deep a question to be solved by the wisdom and philosophy of man. We know that it is so; but the reason of this and other inscrutable phenomena of Nature, must be resolved in the wisdom and will of God.

To the above particulars, from the mineral kingdom, we may add a very powerful argument in favour of an universal deluge, deduced from the distribution of the various kinds of animals over the different parts of the earth; and if this matter be examined impartially, it may be considered as a decisive proof of the question.

We know that Noah's Ark grounded upon Ararat, one of the highest mountains of Armenia in Asia; from whence the inhabitants of the post-diluvian earth, man and beast, were gradually increased and spread over the whole face of the earth.

When Columbus discovered America, in 1492 of the Christian era, there was neither elephant, rhinoceros, camel, lion, ox, nor horse in the New World, nor any other tame nor wild animal that is peculiar to the torrid zone, and to the other warm climates of the Old Continent. Most or all the quadrupeds found in America, were such as are found in cold climates, or indifferently either in cold or warm climates. This remark merits the consideration of natural philosophers. I know very well, that our learned philosophers, who

either deny or doubt the reality of an universal deluge, are very well informed of the comparatively small number of quadrupeds found in America; yet, perhaps, they have not considered this well known fact as having any relation or connection with the proofs of the deluge. But however that may be, I am bold to assert, that this historical fact is a clear proof of that great catastrophe.

I have been long persuaded, that the continent of America is joined to the north-east of Asia; and the researches of the celebrated captain Cook have decided the question beyond a doubt. I am further persuaded, that America was at first peopled by land from the north-east of Asia, and that the native Americans derived their remote origin from some of the eastern Tartars of the cold regions to the north of Corea, or of the northern parts of Russian Tartary. The copper colour, the thin beards, and the general character and manner of living of the northern Tartars, and the Americans, favour this hypothesis. The emigration of the Tartars to America must have happened in a very early period, before the frozen snows of the northern regions were accumulated to such a degree as to block up the passage between the two continents. At present, there is no passage between them by land, on account of the mountains of snow, which have been accumulating for four

thousand years. However, this accumulation of snow would not begin immediately after the flood.

The quadrupeds found in America, when Columbus discovered that continent, would proceed there from the Old Continent long before the rigours of the climate would increase to this extremity of cold. The wild beasts of prey, and such as were not immediately domesticated or tamed for use, would be turned loose in Armenia, to shift for themselves as soon after the flood as the earth was in proper condition to produce fruits, roots, and herbage for their sustenance.

Armenia being situated in about forty degrees of north latitude, such beasts as delight in cold climates would soon spread to the north; and the weak and timid would advance faster than natural inclination prompted them, being obliged to flee from their numerous enemies. These natural causes, and natural propensities, would bring a variety of quadrupeds into North America, before the whole face of the northern regions was covered with eternal snow. Many of the quadrupeds would live in the northern woods for some winters, before they advanced farther south; but most of them would advance rapidly towards the south; the timid being propelled by their enemies, and the carnivorous pursuing their prey. The bear, and other ferocious animals of the cold climates, were found in America when first discovered; but there was neither lion nor tiger, nor any other

of the fierce inhabitants of warm climates, excepting one species of panther, or some other kind of the spotted tribes.

The lama and the pacos are only found in South America, where there is a tame breed of them; they are harmless, useful creatures, but incomparably more slow and phlegmatic than in the wild state. In that state, where they enjoy perfect freedom, and a choice of food and climate, these creatures are exceedingly active and strong, delighting in the regions of snow, among the coldest mountains of South America; and are said to be found among the range of those mountains as far south as Patagonia. In the wild state, the lama is called guanaco, and the pacos, which is the smaller of the two species or varieties of American sheep, is, in its wild state, called *vicuna*. It is said, that the vicunas are still fonder of the summits of mountains, and of the coldest regions of ice and snow, than the lama. Now, the lama and pacos being only found in America, and not in any part of the Old Continent, but in the highest and coldest ranges of mountains in the world, favours my conjecture, that these harmless creatures would wander from Armenia towards the north; and that they might be chased by the American leopard, in a very early age of the world, as far as the Cordilleras, before they found a place of perfect safety from this ferocious enemy. The lama and pacos not yielding such fine fleeces, and

perhaps not such fine flesh as our sheep, and being more capable of securing their own safety among the roughness and cold of the highest mountains, would be turned loose by Noah and his sons. The sheep was more worthy of their care, and they had more need of it, being, comparatively, but slow of foot, timid, and defenceless. And moreover, the first men had no inducement to encumber themselves with the care of any other animals of this kind, as the sheep would afford them abundance of the finest fleeces, and of the best and most wholesome animal food.

Whether we are inclined to suppose that the first emigration of the remote ancestors of the Americans was voluntary, or the result of the fate of war, or other absolute necessity, it will make very little alteration of future circumstances. In this case, the whole horde would remove with all their bestial, and other effects (a short inventory), in the same manner as the hordes of Tartars have in all ages removed from place to place; yet, even upon this supposition, there could be no more domestic animals in America than the Europeans found there in the fifteenth century. Supposing they carried numbers and variety with them, they must all die by the way of cold and hunger, in the inclement and barren regions of the north, which Captain Cook found to be exceedingly extensive.

It may be objected to this, that it is not probable

that the native Americans derived their origin from the Tartars. The Tartars have had the art and custom of taming animals in all ages, and of making use of them for carrying burdens, and for supplying milk and flesh for their subsistence. The Americans, on the contrary, had not the art of taming animals, nor had they any knowledge of their domestic uses when Columbus discovered their country; and therefore it may be inferred, that the original Americans must have arrived there from some island which had not the knowledge and use of domestic animals. In answer to this objection, I would ask, how they could tame and use what they had not, and what was not in their power to have? There was no domestic animal of the Old Continent in all America when Columbus landed there; of consequence, it was impossible for the natives to tame and domesticate what they had not. The only native animals in all America, capable of being domesticated, and made considerably useful, were the lama and pacos; and these were tamed and used by the Peruvians for carrying burdens, and for food and clothing.

Let us now consider the force and import of these facts and reasonings, as far as they are connected with the proofs of the universal deluge.

The records, the traditions, and belief of all antiquity, leave no room for us to doubt that Noah's ark grounded upon mount Ararat in Armenia,

which is situated as near the centre of the Old Continent as can be imagined; a proper centre from whence to distribute all the future inhabitants of the earth, man and beast. America is connected with the Old Continent by the extremities of the north; but the ark, with all the land animals, grounded in Armenia, where they must propagate, and from whence they must spread abroad and replenish the earth. From this arrangement of things, and of situation and climate, only a very few kinds of the large, the noble, and the useful animals, could reach America, and these few only such as could bear the rigours of the north, or that could pass quite through the most inhospitable climate in a short space of time during the summer season; or such as could defend themselves against the effects of the extreme coldness of the climate, and find subsistence by the way to support them during a long peregrination.

If we take but a cursory view of the constitutions of the larger quadrupeds, we shall be convinced, that, according to these observations, not many of them could reach America. Among the harmless and domestic animals, the elephant, camel, bull, horse, ass, sheep, swine, &c. could not bear the cold and rigours of the north; nor could they find proper and necessary food and shelter in passing through it to warmer climates.

Among the large, savage, and ferocious animals, the lion, rhinoceros, tiger, &c. could not bear the cold of the north, or find shelter from the rigours of the climate and seasons.

In short, all things that come under our consideration relating to this subject in both continents, mutually prove and illustrate each other.

I might here produce the evidence of ancient history in favour of the universal deluge, to corroborate and confirm what I have advanced about the distribution of the larger quadrupeds in both continents, as almost all lettered nations have recorded that event, either as a historical fact, or as a generally received tradition; especially the Jews, Egyptians, Babylonians, Greeks, and Romans; and some of the ancient writers upon this subject agree with Moses in the principal particulars recorded in the book of Genesis concerning the deluge; only their account is not so distinct, judicious, and consistent, as that of Moses, whose narrative is perfect, though concise. But I have neither letters, abilities, nor skill, for historical disquisitions; and therefore I will stick to my own province, the Mineral Kingdom, where my labours may be useful, and will leave the historical part to some learned philosopher, who shall be convinced of the truth of my propositions, and of the integrity of my intentions; and from these convictions, shall resolve to complete what I

have begun. Some good philosopher may hereafter think it worth his while to explain and polish my imperfect work, and to add the evidence of ancient history to confirm and illustrate a work of so much importance.

END OF VOLUME FIRST.

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